January 2008

Penetration Depth of Borates in Historic Wooden Structures in Virginia City, Montana

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A thesis in Historic Preservation Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements of the Degree of Master of Science in Historic Preservation 2008.
Advisor: Jake Barrow

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Abstract
Borates have been in use in the timber industry since the 1950s and have proven their worth in fight against fungal decay and wood-destroying insects. In recent years, borates have become frequently employed by the conservation world, not only because the chemicals are effective in preventing wood decay, but because borates have a low mammalian toxicity, are odorless and colorless, and do not interfere with finishes or fasteners.

From Viking warships to historic pianos, borates have been widely used for the preservation of wooden cultural heritage resources. Virginia City, Montana offers a prime test case to assess the performance of borates in historic wooden buildings. Located in the southwest corner of Montana, Virginia City was the site of first gold discovery in the area. The town and its environs are a unique time capsule, with original fabric from 1863 mixed with mid-twentieth century preservation efforts and the nearly archaeological remains of every day citizens - a multi-layered cornucopia of history preserved in the high mountain air.

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A THESIS

in

Historic Preservation

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MASTER OF SCIENCE IN HISTORIC PRESERVATION

2008

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Acknowledgements

I would like to thank the staff at the Montana Heritage Commission, Jeff MacDonald, Jeff Cleverly, Mike Ciani, and Duchess for all their assistant that one cold week in January. Thank you for taking the time out of your day to show me around Virginia City and keeping the ghosts at bay.

I wish to express my gratitude to Dr. Jeff Lloyd at Nisus for his willingness to take a total stranger under his wing and for providing me with crucial guidance when it was needed most.

I would like to thank my advisor, Jake Barrow, for his input during the process, as well as Frank Matero for his guidance and assistance.

A special thanks to James Reidy. You made this process more pleasant than I had any reason to expect.

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Introduction

Borates have been in use in the timber industry since the 1950s and have proven their worth in fight against fungal decay and wood-destroying insects. In recent years, borates have become frequently employed by the conservation world, not only because the chemicals are effective in preventing wood decay, but because borates have a low mammalian toxicity, are odorless and colorless, and do not interfere with finishes or fasteners.

From Viking warships to historic pianos, borates have been widely used for the preservation of wooden cultural heritage resources. Virginia City, Montana offers a prime test case to assess the performance of borates in historic wooden buildings. Located in the southwest corner of Montana, Virginia City was the site of first gold discovery in the area. The town and its environs are a unique time capsule, with original fabric from 1863 mixed with mid-twentieth century preservation efforts and the nearly archaeological remains of every day citizens—a multi-layered cornucopia of history preserved in the high mountain air.

The building stock town is constructed largely of wood and most frequently from lodgepole pine (*Pinus contorta*). The purpose of the following research is to determine if aged wood in Virginia City can be adequately treated with borates in order to protect the fabric from decay mechanisms. Much research has been carried out regarding the penetration depth of water soluble borates, but is always aimed at the lumber industry and testing centers on newly felled lumber. This research will compare aged lodgepole pine samples taken from original buildings with new lodgepole samples taken from the stock of wood used to make repairs in Virginia City in attempts to discover any differences in behavior between new and aged wood.

It is the hope that research conducted will assist the stewards of Virginia City in determining an appropriate course of action as they continue their work towards preserving what is surely one of the finest amalgamations of western history, early preservation efforts, and everyday American life.

Literature Review

Borates have proven their efficacy against a wide range of wood-destroying organisms. Termites, wood-boring insects including beetles and ants, as well as decay fungi can all be adequately controlled with the judicious application of borates. Since the 1940s, borates have been accepted as a suitable wood preservative for building lumber in New Zealand and Australia, eventually gaining acceptance in Europe in 1960s (Murphy 1990). Because of early concerns about the permanence of the water-borne chemicals, the United States has been slow to accept borates into its wood preservative lexicon. Mounting research has begun to change the perceptions of borates and their use in the wood preservation and pest control industries has greatly increased in the United States since the 1980s. Just as borates have gained acceptance in the wood industry for the preservation of new lumber, their use for remedial treatment of existing and historic structures has likewise grown.

History of Borates

Modern wood preservation started in 1838 with the development of creosote impregnation under pressure (Connel 1991). In the early twentieth century, other preservative formulations containing fluoride, arsenic, and chrome were developed. The earliest use of boron in wood preservation was in 1913 as a chromium borate mixture (Lloyd 1998).

Research in the United States did not begin in earnest until the 1970s when the USDA Forest Service's Southern Forest Experimentation Station initiated efforts to control recent powderpost beetle infestation in imported wood (Williams 1991). The research blossomed into a multi-organizational effort including Mississippi and Oregon State Universities as well as many cooperating industrial pesticide firms (Barnes 1989). This research marked the beginning of renewed interest in water-diffusible pesticides, with First and Second International Conference on Wood Protection with Diffusible Preservatives and Pesticides being held in 1990 and 1996.

Currently, there are several borate treated lumber products available for construction purposes. The lumber is pressure treated with borates and marketed for indoor framing and sill plate construction. Additionally, use of borates in the pest control industry is on the rise, with a 10-15% increase in the use of borates since their introduction in the early 1990s (Potter 1996).

Efficacy as a Pesticide

The ability of borates to control wood deterioration is not up for debate. A large body of research exists demonstrating just how effective boron-containing compounds can be against the major enemies of wood (Clausen 2007). In New Zealand, the lumber industry has been pretreating radiata pine with borates since the 1950s. Concerns over the susceptibility of the non-native, sapwood-rich species to native wood-boring insects inspired the search for an immunization treatment as the first crop of trees came to maturity in the late 1930s (Cross 1992). Treatment with borates became the obvious choice due to its economical nature, being one forth the cost of pressure treatment with chromated copper arsenate (CCA). The treatment proved so effective that insurance agencies in New Zealand now require any frame house built with radiata pine to be treated with borates. In Cross's review of the literature, he found that there has not been a single case of failure due to wood deterioration in borate-treated lumber (1992). In fact, most reported cases of failure come from native species, supposedly naturally resistant and therefore left untreated.

In Hawaii, which is battling against the aggressive Formosan termite, all construction lumber must be pretreated with some sort of pesticide and borates are beginning to be accepted into the regime (Manning 1996). To trust borates with such an important job—protecting a structure from an insect which can totally destroy a home in two years—shows that the efficacy of borates has been well accepted.

Boracol 40 (manufactured by BiokilCrown), a borate solution in ethylene glycol was shown to be 100% effective when preventing powderpost beetle infestation in messmate trees (*Eucalyptus oblique)* (Creffield 1983). No signs of infestation were seen in the pretreated samples after five months of exposure to powderpost beetles. The same study applied Boracol as a remedial treatment by first allowing powderpost beetles to infect the wood and then applying treatment. This method was nearly as effective as pretreatment—only minimal signs of infestation were visible. This study is particularly relevant to Virginia City, Montana, as entire beams have needed to be removed from buildings after being totally ravaged by powderpost beetles.

There are many products on the market that can make similar claims regarding efficacy against biological wood deterioration mechanisms. Pesticides such as creosote and CCA have longer track records than borates in terms of wood preservation. However, borates offer a long list of benefits that most standard wood preservatives cannot match.

Benefits of Borates

Toxicity

Borates have a very low mammalian toxicity. The LD-50 for boron, which is the lethal dose needed to kill 50% of a sample population, is 3500 mg per one kilogram (Currie 1996). By comparison, pentachlorophenol, commonly used to pressure-treat utility poles and railway ties, has an LD-50 of 125 mg per one kilogram (Currie 1996). Other research has shown that very little boron is absorbed through the skin, often less than 1% per dose (Wester 1998). Even if boron is ingested or absorbed, it has a biological half-life of less than one day and is easily excreted by the kidneys (Mastromatteo 1994). Additionally, borates are non-volatile and do not adversely effect air quality with their vapors (Currie 1996).

The average adult consumes approximately 1 mg of boron per day, according to the Environmental Protection Agency's "Health Effect Support Document for Boron." The same document reports that 75 million Americans are exposed to boron in their drinking water, but at levels well below any need for concern. Boron occurs naturally in plants and is considered a necessary micronutrient for plant health (Currie 1996). Furthermore, boron is considered nontoxic to fish, aquatic invertebrate, and birds (EPA, Health Effects).

The low mammalian toxicity in combination with its ubiquitous presence in nature and benign interaction with non-targeted animals makes borates an ideal wood preservative as the conservation field incorporates the green movement into treatment protocol. Borates allow for treatment without turning a historic site into a toxic waste dump or creating hazardous conditions for workers.

Interaction with Historic Material

Pertinent to the field of conservation is how borates interact with other materials, particularly finishes and fasteners. It is generally accepted that borates do not adversely affect finishes or interact poorly with metal fasteners. Pinellas County Heritage Village treated an historic organ with Jecta (a thick boron paste manufactured by Nisus) and no adverse affects were noted on the finishes (Stanley 1999).

A study applied BoraCare (disodium octaborate tetrahydrate in ethylene glycol manufactured by Nisus) to samples of clear white pine and then applied a range of coatings found typically in home construction (Palmere 1990). These included an alkyd stain, a semi-transparent oil stain, a solid color latex stain, a transparent latex stain, a latex/water repellent stain, and solvent/paraffin sealer, and an exterior latex paint. Results showed that BoraCare treatment did not negatively affect the five categories of adhesion, checking, water resistance, durability, and appearance and in fact seemed to initially improve color retention and UV resistance.

Ease of Application

Perhaps the most useful characteristic of borates is the ease which with they can be applied to wood. Williams makes the case for dip diffusion treatments of newly felled lumber in 'developing' countries, because all that is needed is a vat large enough for submersion and a place to store the treated wood (Williams 1991 41). The implication is that is that very little money is necessary to start dip diffusion treatments of timber, and this idea has positive ramifications for the test case of Virginia City. All the replacement repairs are done with locally milled, unseasoned lodgepole pine, a prime candidate for dip diffusion treatment. One could easily make the case for pre-treating all replacement wood in Virginia City, much like protocol adopted by the Maritime Trust in the United Kingdom after their experience with borates (Dickinson 1990). The Trust found that pre-treatment of their in kind repairs was the most effective way to prevent deterioration.

Problems with a Water Soluble Preservative

Despite being easy to apply, exhibiting low mammalian toxicity, having very little negative environmental impact, and being highly effective against many bio-agents that ail wood, there is on major drawback with borates—their high solubility in water. Just as borates can diffuse into wood using free water within wood cells, so too can they diffuse out, and this attribute has long been blamed for the delay of acceptance of borates outside of New Zealand and Australia (Williams 1990). It was assumed that because borates cannot be fixed in the wood the chemical would necessarily leach out if left in wet soil contact or exposed to cyclical wetting conditions. For this reason, borates are only recommended for use in situations where wood will be above ground and protected, either by shelter or coatings. Recent research as well as several reviews of the existing literature have called into question the real threat posed by leaching.

In order for leaching to occur, wood must remain wet across its entire cross section and there must be an external sink into which borates can diffuse, either in the form of wet soil or water running over the surface of the treated wood (Manning 1996; Williams 1991, citing Harrow 1959). Even if these circumstances are met, several studies indicate that leaching does not reduce levels of borates below those necessary to control pests. In a review of leaching research, Lloyd draws the conclusion that the problems associated with leaching were initially overstated (1995). He cites one study showing that even with a 30% BAE (boric acid equivalent) loss after six months of exposure, high enough levels to remain effective were retained within the wood. Boric acid is considered the 'active ingredient' in borate preservatives with BAE being calculated on a weight/weight basis of boric acid to wood. Lloyd's review includes many other studies supporting the idea that leaching may not necessarily equate loss of efficacy. In fact, the very mechanism which leads to leaching can result in further penetration by redistributing borates deeper into the wood.

The major point made in Lloyd's review of leaching is as long as initial loading is high enough final levels of borates—even after leaching—will likely remain effective. He points to several studies that suggest that leaching tapers off well above levels considered adequate for protection.

After thirty months of outdoor exposure, wood samples treated with Tim-Bor [disodium octaborate tetrahydrate (DOT) in water manufactured by Nisus] were placed in jars with termites (Williams 1991). After six weeks exposure, the samples were removed and weight loss was determined as a measure of how well borates prevented the termites form feeding on the samples. Results returned weight losses around 2%, which amounts to "surface nibbling" by the termites. Williams' study supports Lloyd's idea that borates are more likely to distribute deeper into the wood than out of it during wetting. When they analyzed boric acid content in the outer versus inner section of the wood samples, the top sections showed a decrease, while the inner sections showed an increase in levels of boric acid (Williams 1991).

Unpublished work cited by Williams has shown that leaching can be a positive attribute, because borates can migrate to untreated wood if there is sufficient moisture from condensation (1996). Additional studies have shown outdoor exposure is not enough to reduce the efficacy of borates (Murphy 1996, Manning 2004). The most dramatic example is also unintentional. A housing development in New Zealand erected borate-treated framing, but the company went under before the roofing went up. After five years of exposure to 55 inches annual rainfall, the framing remained intact. Visual inspection confirmed lack of deterioration as compared to the untreated flooring material and lab analysis confirmed sufficient levels of borates within the framing, well above minimum accepted levels. (Manning 1996, citing Anonymous 1994).

Necessary Levels

What is considered sufficient levels of borates for wood protection? The answer is not as straightforward as one simple number. The New Zealand Timber Preservation Council requires 0.1% boric acid equivalent (BAE) within the inner 1/9 core of sapwood (Vinden 1990). Studies have recommended BAEs as high as 0.5% when combating termites (Drysdale 1994) and as low as 0.02% BAE for certain types of fungus (Manning 1996, citing Morris 1997).

Further complicating the matters is that laboratory testing and field testing often differ. A study by Archer showed that 0.1% BAE was effective against Formosan termites in the lab but not in field testing in Hawaii. The inconsistent results are blamed on the lack of real standards in the field and the wide array of pests being tested (Peters 2006). It is generally accepted that 0.2% BAE is sufficient for control of fungal decay, termites, and wood boring insects (Amburgey 1990, Drysdale 1994).

It is not necessarily difficult to achieve efficacious levels of boron loading on unseasoned wood. What becomes problematic is the question of penetration. The lumber preservative industry seeks out total penetration and protection. A common example of insufficient penetration is the pressure treated board with an intact exterior shell and a completely deteriorated interior. Much research has been devoted to determining if a concept as simple and passive as diffusion can compete with more aggressive methods such as pressure treating.

Factors Effecting Penetration Depth

There are many factors that contribute to penetration depth of borates in wood. Moisture content is the factor that contributes most directly to penetration, but as it is the most problematic in Virginia City, it shall be discussed last. Other factors include temperature, solution concentration, and density of wood.

Borates penetrate woods with lower density with greater ease than heavier woods (Williams 1991). In Virginia City, this is a pertinent issue as the original wood stock was much older and likely denser than the younger growth replacement lumber currently being felled.

Solution concentration contributes to final loading. The higher the initial concentration, the higher the final loading, but the benefits of increasingly concentrated solutions level off at 25% BAE (Archer 1991, citing Fowlie 1988). Additionally, it has been found that thickened borate solutions such as Diffusol, BoraCare, and Boracol (DOT in ethylene glycol) penetrate wood faster and with higher BAE than heated water based solutions (Greaves 1990; Vinden 1990; Williams 1996, citing Grace 1994). Vinden attributes part of this to the lower surface tension of these thickened solutions when diluted with water.

Temperature plays a key role in diffusion as well. The solubility of boric acid is directly proportional to temperature, which could explain why diffusion rates doubled for every 20ºC (Williams 1991). Increase temperature can apply either to the environment in which diffusion takes place or to the solution. Increased drying temperatures of pine boards led to a decreased drying/diffusion time of several days compared to several weeks drying at ambient temperatures (Archer 1990, citing McQuire 1972).

The positive effects of temperature and thickened or heated solutions on diffusion depths could be used to counteract a possible problem with the use of borates in Virginia City: moisture content.

Moisture content (MC) is by far the most important factor effecting penetration depth. Diffusion begins at fiber saturation point (30% MC). Fiber saturation point is defined as the point at which all cell cavities are empty of water, but cell walls remain saturated with bound water. Several studies have found that 40% MC is necessary for proper diffusion

(Schmidt 1990, citing Morrell 1990; Williams 1996, citing Borax Tim-Bor treatment manual; Williams 1990). This not a problem for researchers in the lumber industry, as the research focuses on unseasoned wood with very high moisture contents.

Remedial Treatment with Borates

Unfortunately, resources within the historic preservation are not so easily controlled as those in the lumber industry. In some instances, the fact that borates diffuse well in high moisture content situations could be seen as an excellent attribute. This is especially true in maritime instances when MC may be above 100% and removing the source of water is impractical. However, remedial treatment of drier timbers at MC below that which allows for easy diffusion but above that which supports deterioration mechanisms presents a special set of problems. Drywood termites, fungi, and powderpost beetles all survive at MC well below 40% (Potter 1996).

The advent of thickened borate solutions seems to fill this niche quite well. BoraCare (DOT in ethylene glycol) gave twice as deep penetration (1/2") to pine floor boards as compared to DOT in water (Williams 1996, citing Puettmann 1992). The same study also noted better penetration of wood that had been in service for many years as opposed to new kiln-dried wood. This is likely due to the increased surface area of wood in service, developed from general surface roughening as well as checking. Other studies make note of the fact that rain water accumulating in checks can serve to redistribute borates (Amburgey 1991).

The use of borates in drier, aged wood samples becomes something of a game of tug of war. Pulling in one direction is the increased uptake due to higher surface area assisted by higher loadings using thickened solutions. Pulling in the other direction is lower MC, acting as a deterrent to adequate penetration. Several case studies in the literature illustrate that, despite the difficulties, borates can be an effective tool to combat wood deterioration in historic wooden structures.

Case Studies

One of many maritime examples, the Swedish warship *Wasa* presents an excellent use of borates for cultural resource management. Sunk in 1628 and resurrected in the early 1960s, the waterlogged vessel needed preservation. The ship was treated with a mixture of boric acid and borax in polyethylene glycol (Dickinson 1990). After several years and a few failed repairs, the conservation crew adopted the policy of pre-treating any replacement wood (Dickinson 1996). The initial treatment with borates adequately preserved the ship for future generations.

Several other instances exist of borates being used on water logged vessels. The schooner *Wapama* was treated with Tim-Bor (DOT in water) to control fungal decay during drying (Dickinson 1996). It was found that two inches of penetration were achieved after six months of treatment, involving repeated spraying of the entire ship (Birkholz 1989). The solution proved so effective that the San Francisco Maritime National Historic Park, where the *Wapama* was treated, incorporated borates into their Integrated Pest Management Program in 1985 (Casebolt 1999).

Henry VII's flagship *Mary Rose* was re-floated in 1982 and treated much in same fashion as the *Wasa* (Dickinson 1990). The Maritime Trust of the UK treated the *R.R.S. Discovery* with hot solutions of borates and found it very effective for controlling fungal damage in infected timbers (Dickinson 1990).

Moving inland, but not too far from the ocean, Sitka National Historical Park in Sitka, Alaska began treating totem poles located in the park with borates in 1992 after decades of being treated with wood preservatives as diverse as creosote, sodium fluoride, and mineral oil (Sheetz 1996). Solid DOT rods were inserted in places of likely water accumulation, like joints and newly drilled holes for rods, while BoraCare was applied over the rest of the structures. After four years, 1-3/8 inch penetration was found with a BAE of greater than 0.25%, sufficient to protect the totems from insect and fungal damage.

Facing similar problems was the team treating the *Labyrinth* by Francois Stahly, a large iroko wood sculpture installed outdoors at the state capital complex in Albany, NY. Treatment of the sculpture utilized solid borate rods, glycol-based solutions in addition to pastes to treat the sculpture comprehensively. The carpenter ants had disappeared after two years and the brown rot fungal damage was likewise brought under control (Glover 1997).

Traveling back across the country to southern California, we find an example of borate use that better approximates the conditions of Virginia City. While at first glance Los Angeles, California and Virginia City, Montana may seem to have very little in common, they share one important factor: both cities lie in very arid climate zones. Dominguez Rancho Adobe (1826) located south of Los Angeles is believed to be the oldest house in southern California. The house is both a California Historical Landmark and on the National Register of Historic Places. After a comprehensive treatment with BoraCare, TimBor, and Jecta (a thickened borate paste) the dry-wood termite and brown rot problems within the wooden beams of the adobe structure were brought under control (Lively, date unknown).

The review of the literature regarding borates reveals a rosy outlook for using borates in Virginia City. Borates have a distinguished pedigree in the lumber protection field, with over sixty years of hard data to back up claims regarding efficacy against all manners of pests that seek to destroy wood. While making the switch from preventative conservation to remedial conservation efforts may take several years of re-education, existing research and practical experience support the idea that borates can be used successfully in the efforts to preserve and protect the historic resources within Virginia City.

Borates: Their Function

How Borates Work

The complexation of borate ion with poly-ols necessary for fungal metabolism explains how the chemical is not a biocide so much as it is biostatic. That is, borates do not kill organisms actively, but interfere with normal metabolic processes and starve the organism. An experiment testing this hypothesis added varying amounts of sugars or sugar alcohols to a borate solution. Borates are known to form easy complexes with these types of molecules. Results form the experiment indicate that pre-complexed borate solutions are less effective at inhibiting growth of various molds and fungi and this result implies the complexation action of borates with molecules in the organism is necessary if borates are to inhibit growth of organism (Lloyd 1990).

It is known that borates are necessary for plant life and that the element can not be replaced with another. What is not known however, is what specific function boron is necessary to, although its link to some reproduction functions is suspected. However, the exact role of boron is still unknown. It is not is currently understood how borates kill insects, but it is assumed that the mechanism is similar to the effect of borates on fungi. That is, that borates interfere with some necessary function of the insects, likely a metabolic function.

Site History and Condition

The story of Virginia City begins with a simple need for tobacco money. Weathering the ups and downs of a gold rush, the town clung to survival with characteristic western tenacity. When one man with a penchant for collecting buildings came along, the story changed directions drastically, quitting the path of a derelict gold rush town and jumping on the preservation wagon trail.

Enough Money to Buy Some Tobacco

On May 26, 1863 a group of six men, weary from an ill-fated trip to meet a larger gold mining party, made camp near a gulch filled with alder trees. An excerpt from one of the men's diaries details the account.

> "There is a piece of rimrock sticking out of the bar over there. Get the tools and we will go and prospect it." Bill got the shovel and I the pan and went over. Bill dug the dirt and filled the pan. "Now go," he says, "and wash that pan and see if you can get enough money to buy some tobacco" (Pace 1962).

In fact, the men discovered over $250 in today's value of gold dust in just a few minutes. Attempts to be discreet were met with limited success. The men returned to the nearest town to gather supplies. When it was time to return to the site, the small band of men found themselves in the company of at least 300 gold miners wishing to be shown the way to Alder Gulch.

Discovery of gold in Montana occurred well after the initial gold rush of the west, and consequently, the settlement of Virginia City was calm and orderly owing to the experience the founders had in other gold boom towns. Three days after the return to the gulch, a governing structure was put in place and the elected judge signed the document which officially named the town Virginia City (Pace 1962).

In less than one year 10,000 people were living along the 14-mile gulch with Virginia City at the center, and this boom directly effected the character of the building stock within the town. There are three phases in gold boom towns, with each phase usually being cast aside for the next, but in Virginia City, the growth was so rapid, that there was no time to remove old buildings to make way for new—they were simply incorporated into new construction. By 1865 Virginia City had progressed from the settlement phase, characterized by impromptu dwellings thrown up by miners concerned only with gold, through the camp phase, marked by slightly more permanent buildings, and on to the town phase (Canfield 2007).

At the time of discovery, Alder Gulch was part of the Idaho Territory, but new riches in the area along with an increase in population prompted creation of a new territory of Montana in May of 1864. Virginia City became the territorial capital of Montana in 1865, holding on to the title for ten years, eventually losing to Helena after a series of scandals, recalled votes, and trials to rival any presidential election (Baumler 1999).

Decline And Survival

Virginia City has never been a ghost town. As hard hit as it may have been by the loss of the capital title, the decline of the mining business, world wars and the Great Depression, Virginia City has held on. With the newly arrived automobile culture in the 1920s and subsequent growth of the family vacation, Virginia City began to see some relief in the form of the tourist dollar. Even though the city had lost much of its original building stock, the town still presented an authentic picture of the Wild West to traveling families. Those traveling to Yellowstone National Park often stopped in Virginia City for a peek. However, World War II and the Gold Mine Closing Order stopped all non-essential industries and gold mining ceased. Tourism was helpful, but was nowhere near self-supportive (Baumler 1999). The buildings needed care and protection, but no one in the town was willing to take on the job.

The Bovey Era

Charles Bovey entered the story of Virginia City at a crucial point. The town could not afford to preserve their rich historic resources and the mining industry had left completely. At a time when the country was looking to all things modern, Charles Bovey sought to hold on to the past. For years before settling in Virginia City, Bovey roamed Montana with his wife Sue buying historic objects. Not one to limit himself to artifacts, Bovey bought entire buildings, relocating the majority of them to Great Falls, Montana. The “Old Town” exhibit, created in the early 1940s as a part of the state fair lasted more than 20 years (Canfield 2007).

When the Boveys first visited Virginia City in 1944, they saw a crumbling town in need of much repair. Recognizing the historic value of the town, Bovey immediately began work to save the town. He bought up as many buildings as he could, eventually establishing the Historic Landmark Society of Montana whose stated purpose was the preservation of the historic structures in Virginia City. Financed entirely by Bovey and his access to the General Mills fortune, Virginia City was transformed from a fading mining town on the brink of extinction into a bustling tourist attraction.

Bovey's original intent was not to attract tourists, but they came anyway. When the city officials in Great Falls decided the space taken by "Old Town" was needed for other purposes, Bovey moved everything to Nevada City. Located just one mile down Highway 287 from Virginia City, Nevada City was once part of the 14-mile boom town. Mostly lost to aggressive mining, Bovey recreated the entire city with his collection of buildings from across Montana.

Not only did Bovey collect buildings, but he sought to fill them with appropriate artifacts. To this day there are dry goods, clothing, candy, make-up, shoes, buttons, thread, and long underwear, along with other countless everyday items still in their original packaging filling the buildings of both Virginia City and Nevada City (figure 3.1). Some of the items were left behind when residents died or abandoned their homes, but most were acquired

Figure 3.1: Everyday items on display at Virginia City in Room H (see illustration 3.1, p29).

by Bovey over the years.   Bovey wanted to bring the past alive, going so far as to put mannequins in the front rooms—citizens getting a shave or buying a new hat.

Bovey made repairs where necessary, but generally preferred to retain the aged appearance of the town. He was not opposed to replicating buildings from historic photographs, and to the untrained eye, distinguishing a Bovey Era reconstruction from an original building can be difficult (figure 3.2) Bovey's restorations and reconstructions also served to preserve some of the intangible aspects of western life. He employed local traditional craftsmen to carry out much of the work. Some of Bovey's methods, however were less than traditional.

Figure 3.2: Army barracks disguised to look like part of the old town, installed by Bovey in the 1950s.

The same creek responsible for the gold boom in town is also in part responsible for failing foundations. The creek runs underground though parts of the town and the elevated water table has seriously compromised the sill plates and spandrel log courses in many buildings. Bovey's response was to remove the rotted wood foundations and replace them with what current preservation staff have deemed "Bovey back fill," a hodgepodge concrete mix that serves mainly to trap water against the wooden buildings and accelerate decay (Canfield 2007).

Bovey died in Nevada City in 1978, leaving his life's work in the hands of his wife. Sue Bovey carried out the work until her death in 1988. Their son had little interest in preservation and the town again entered a state of decline. The National Park Service originally investigated taking over the site, but viewed it as too much of a financial burden. In April of 1997 the state of Montana stepped up and purchased the property after much support from the citizens of the state, paying $6.5 million for 250 buildings, 160 acres and countless artifacts. (Canfield 2007)

The Montana Heritage Commission

After the purchase of the site, the state legislature created the Montana Heritage Preservation and Development Commission, generally referred to as the Montana Heritage Commission (MHC). The organization bears the responsibility of protecting the historic fabric while encouraging "economic independence" of historically significant sites. (Canfield 2007) For Virginia City and Nevada City, the burden of preservation falls on a small staff of preservation specialists who must fight the tide of deterioration, trying to stay one step ahead of Mother Nature and her relentless desire to return Virginia City to the hills from which she sprang.

The Kraemer and McGovern Buildings

Situated at the western end of Wallace Street towards the edge of town, the Kraemer and McGovern Buildings are a testament to the nature of growth in Virginia City (see figure 3.3). Construction began in 1863 and continued through various additions and renovations until the early twentieth century. The layers of history visible remain intact as residents

Figure 3.3: The Kraemer and McGovern Buildings.

Figure 3.4: Many layers of decoration evident in Room V (see illustration 3.1, p29).

simply covered old with new and the Bovey mentality was to leave well enough alone (figure 3.4).

Three of five front rooms have been restored through Bovey's efforts to represent commercial life in a western town. The quantity and quality of goods found on display within these rooms is astounding, and if weren't for the fine layer of dust settled on every surface, one could almost expect a vigilante to walk through the doors looking for a new pair of long underwear (figure 3.5). The rooms behind the publicly viewed commercial spaces are another matter. These areas currently act as informal storage for the Bovey collection or are ageing time capsules of long gone residents (figure 3.6). Photographing one room in particular (room C on plan, illustration 3.1) felt like trespassing, with the resident's coat on a hook by the door and a box of Kraft Dinner under the sink contributing the feeling that someone was going to come home any minute and be quite surprised to find a graduate student documenting his living space (figures 3.7 and 3.8).

The buildings present a unified front when view from the street, but the labyrinthine interior reveals the organic growth commonplace to frontier era construction. The three spaces obvious from the street are defined by structural log walls. The eastern and middle sections are divided with partition walls into two spaces, with the wider section towards the east. The spaces between the log walls are interconnected, but communication through the log walls is limited to one opening between the middle and eastern buildings (see illustration 3.1). Staff members at the Montana Heritage Commission expressed doubt over the intelligence at cutting a large opening in a load-bearing log wall and could offer no real explanation as to why it had been done. The ways of the frontiersmen are indeed mysterious.

Figure 3.5: Everyday items on display in Room H, including never worn period shoes (see illustration 3.1, p29).

Figure 3.6: Informal storage in Room B (see illustration 3.1, p29).

Figure 3.7: Coats left by the owner on the hook by the door in Room C (see illustration 3.1, p29).

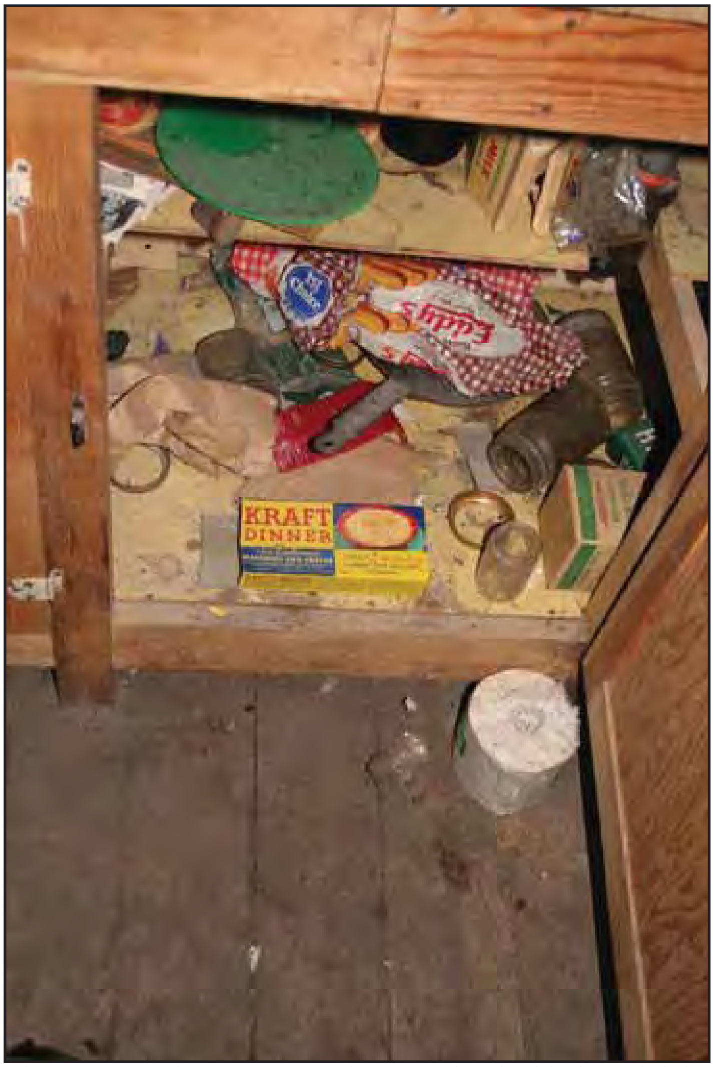


Figure 3.8: A box of Kraft Dinner under the kitchen sink in Room C (see illustration 3.1, p29).

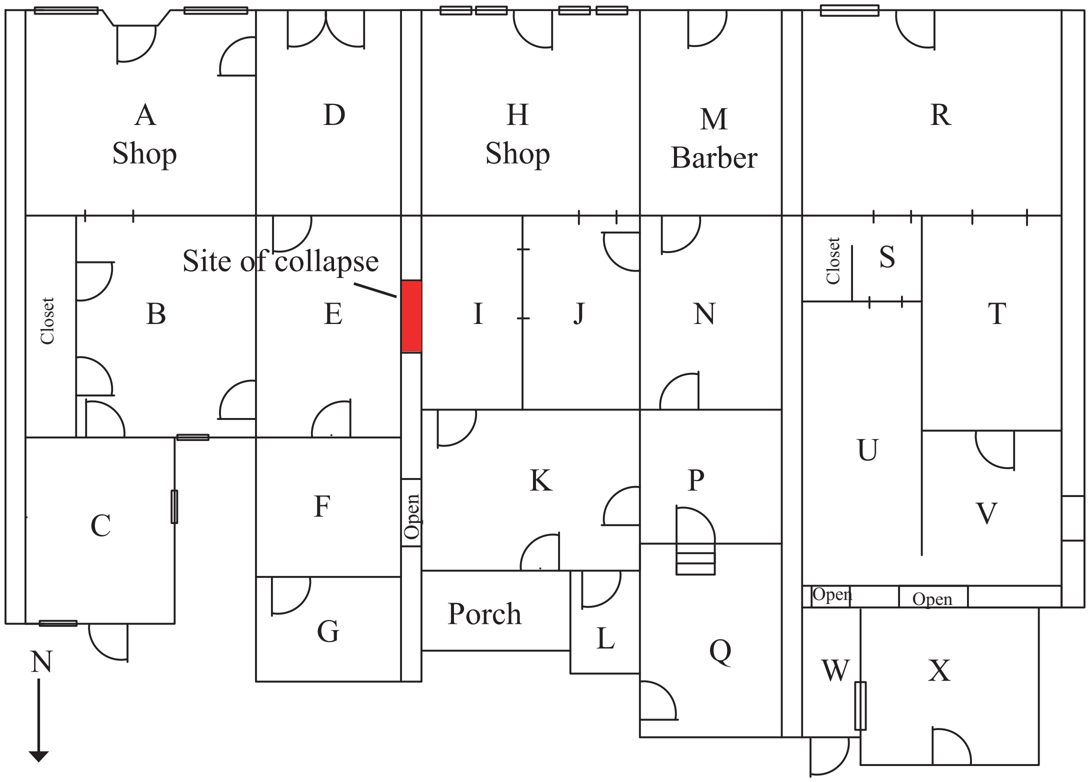


Illustration 3.1: Floorplan of Kraemer and McGovern Buildings. The Kraemer Building consists of Rooms R through X, on the right third of the plan. The McGovern Building is the remaining portion. Load-bearing log wall are denoted by double-thickness lines, and frame walls are denoted by single-thickness lines. Drawing not to scale.

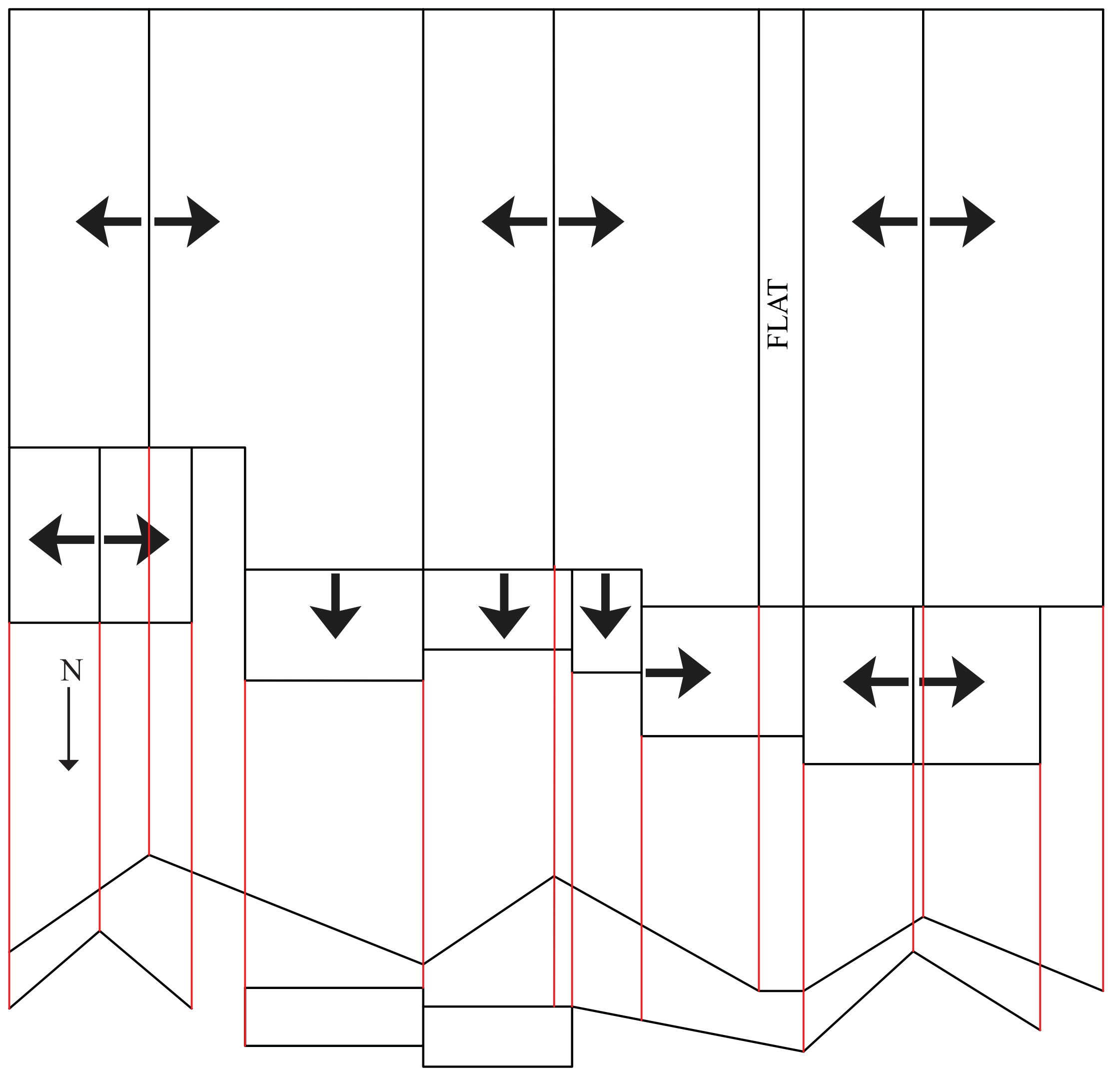


Illustration 3.2: Conjectural roof plan and roof line of the Kraemer and McGovern Buildings. While the drawing may not be exact, owing to large quantities of snow at the time of survey as well as limited access, the many peaks and valleys are visible and apparent. Arrows indicate direction of downward slope. Drawing not to scale.

Decay in Virginia City

The opening in the log wall may have contributed to a collapse further south in the same wall. Generally, the interior of the log walls were covered with either cotton muslin or lathe and plaster and the extent of the damage was uncovered during an investigation by MHC in the fall of 2007 revealed that a large portion of the log wall had collapsed (figures 3.9, 3.10) . Inspection of the wood at the site of collapse showed signs of advanced fungal decay. One of the necessary factors for fungal growth is adequate moisture, and even though Virginia City maintains a dry climate, the construction of the building serves to channel the scant precipitation into dark and hidden areas.

Common log walls sit at the valleys in the roof line. These roofs are not uninterrupted surfaces but a conglomerate of roofing material patched together as the buildings grew. As a result, the connection between roofs is likely a place of water infiltration and serves to explain why a wall several feet above the ground line in a dry climate succumbed to fungal decay. Illustration 3.2 contains an estimated drawing of the roofline and illustrated just how intersections are present in the building.

An additional problem in Virginia City is the powderpost beetle, a broad name for several species of wood boring insects. Damage from these insects results when the eggs laid on the surface hatch and larvae tunnel into the wood. The larval insects eat cellulose, leaving behind powdery frass and extensive channels in the wood. As the insects leave, they create unsightly exit holes up to 1/8" in diameter, generally concealing the damage until the end of the insect's life cycle. Serious infestations can compromise the structural integrity of a wood.

Damage from powderpost beetles is not limited to the Kraemer and McGovern buildings. A lintel pulled from the Gilbert Brewery on the east side of town had been completely


Figure 3.9: The collapsed wall between Rooms E and I. Temporary shoring was put in place to prevent total collapse.


Figure 3.10: Interior view of collapsed wall, showing severely deteriorated wood.

destroyed by the insects, with parts of the beam resembling a sponge and the only course of action left was total replacement (figures 3.11, 3.12). With their lower limit for survival between 10% and 15% moisture content, these insects do not need as high a moisture content as fungi. A cursory investigation of moisture content reveled that *in situ* historic wood maintained a moisture content between 10% and 12%, well within the range for powderpost beetle attack.

Virginia City has been dealt a better hand than most western boom towns. Founded on the riches of the "auriferous gravel" in her streambeds, blessed by founders with their heads on straight and the good fortune to be the home of some of the more wild stories to come out of the old west, Virginia City seemed destined to survive. Located in a dry climate and miraculously never the victim of a massively devastating fire, the physical remains of the rich history embodied in the site have withstood the ravages of time where many towns have faded away. Add to all this a man with preservation in his heart and the General Mills fortune in his bank account and the odds start to look even better. Even though many of the buildings are in desperate need of attention, state ownership of the historic landmark provides extra insurance for the lasting survival of Virginia City.

Figure 3.11: Damaged lintel, showing extent of damage done by wood-boring insects.

Figure 3.12: Detail of damaged lintel. Cross-grain cracks are evidence of brown rot fungal damage, often seen in conjunction with wood-boring insect damage.

Testing Protocol: Methodology

The following testing protocol follows very closely with industry standards for applying borates in solution to wood samples in order to ascertain penetration depth through colorimetric testing. The experiment differs mostly in sample selection and application method, as it seeks to replicate remedial treatments for existing historic fabric, whereas industry tests study factory-applied, whole surface applications with newly felled lumber.

Sample Gathering

The first step required sample gathering. During a site visit to Virginia City, Montana, one structure was selected that was representative of the building stock within the town. The McGovern buildings met the requirements set by the researcher as follows:

1. Load-bearing construction materials wholly lodgepole pine.
2. Structure original to initial building phase of Virginia City (1863).
3. Bio-deterioration of wooden elements prevalent.
4. Samples available for collection.

Several types of samples were gathered from the McGovern buildings in the form of a collapsed partition wall being rebuilt during the visit. This yielded an approximately 5-foot length of log that removed from the building by chainsaw (figure 4.1). The severely decayed end, exhibiting deterioration consistent with fungal wood rot was removed, leaving about 2 ½ feet of sound log for experimentation. The log was further cut into smaller sections, averaging 4 inches in length for ease of transportation back to the Architectural Conservation Laboratory at the University of Pennsylvania.


Figure 4.1: Historic log before removal for experimentation.

One piece of dimensional lumber in the form of exterior cladding was likewise removed from an inconspicuous part of the building. These two pieces of lumber represent a large percentage of lumber types within Virginia City, accounting for the load-bearing log construction as well as the exterior cladding found on most buildings.

Non-historic samples were gathered with an eye towards mimicking the historic samples previously gathered. These were culled from the replacement building material stock kept on hand by the Montana Heritage Commission. Their repair shop located in town contains a large assortment of dimensional lumber and logs used to make repairs and replacements on the buildings within Virginia City. Rough cut dimensional lumber is obtained from Nygren Sawmill in Argenta, Montana, approximately 70 miles west of Virginia City. Logs are obtained from different sources, either local builders or a mill near Helena, although local sources are preferred.

Collecting dimensional lumber samples was a matter of sifting through the available material and selecting pieces best suited for experimentation, namely those pieces of similar thickness to the historic wood (around 1”), and pieces free of serious defects in the form of knots, cracks, or other obvious surface irregularities.

The replacement log collected for the experiment was taken from the yard at the Virginia City shop. It is common practice on site to leave logs in the open in order to weather them such that they lose their newly felled appearance and better blend with historic fabric when installed in the buildings. The log chosen had a larger diameter than the historic log. The non-historic log sample was cut from a larger log with a chainsaw, and the bark removed with a draw knife. The bark was removed to simulate the condition of the historic log, which may have been installed bark on, but have since lost that layer. After bark removal, the log was cut into smaller pieces to aid shipping.

After gathering all the necessary samples, the moisture content of each piece was documented using an electric GE Protimeter. Each piece was wrapped in plastic, using a household garbage bag, packed in a cardboard box with sufficient foam packing material to prevent movement and shipped via US Postal service from Virginia City to the Architectural Conservation Laboratory at the University of Pennsylvania.

Sample Preparation

Conditioning the samples began almost immediately after their arrival back at the lab. The first step was to divide the wood equally in to four sample sets.

Sample Set 1: 20% MC and 15% DOT in water

Sample Set 2: 40% MC and 15% DOT in water

Sample Set 3: 20% MC and 1:1 DOT in glycol

Sample Set 4: 40% MC and 1:1 DOT in glycol

The larger pieces were then cut into smaller pieces, such that no less than two square inches of surface area would be available for treatment. This was done to insure an even distribution of wood types in each sample set. The historic wood log was divided into four pieces cut perpendicular to the grain, yielding four disks and each set receiving one piece. The pieces were labeled 1 through 4, according to their position in the whole log and given the prefix HWL (historic wood log). Sample number of the historic wood board corresponded to the sample set number.

The historic wood board was cut into twelve pieces each approximately two inches wide. The cuts were made perpendicular to the long edge of the board and the pieces were numbered 1 through 12 and catalogued with the prefix HWB (historic wood board). Due to a large check in the wood, HWB12 broke into two pieces during cutting, HWB12A and HWB12B.

The new log was cut into five sections perpendicular to the grain in similar fashion to the historic log and these were numbered according to their original position in the whole log. Section three was discounted as it was considerably smaller than the other sections, the impromptu original cut being made in the field by chainsaw. The remaining sections were further subdivided into four pieces. The cuts were made to yield roughly the same treatable surface area when compared with other samples from the same section. Using the center of growth rings as a locus point, the log sections were cut in half, yielding two sections of equally surface (but with different volume). The halves were halved again, with the cut extending from the central growth to a point on the exterior surface such that the end pieces were of similar surface area. The four sections were reassembled and numbered clockwise starting with the upper right piece one through four and including the original section number and given the prefix NWL (new wood log). For example, the first subsection was numbered NWL1.1. It is recognized that this system of numbering is rather arbitrary, as there is no real 'upper right' on a cylinder.

The new boards were cut into smaller pieces and numbered similarly to the new logs in that the whole piece was given a number one through seven and each smaller piece from that given an additional number with the prefix NWB. Each piece of new board generally yielded four smaller pieces, with the exception of NWB6 with yielded twelve pieces.

The following table details the sample numbers in each set.

	Sample Set 1	Sample Set 2	Sample Set 3	Sample Set 4
HWL	1	2	3	4
HWL	1, 5, 9	2, 4, 10	3, 7, 11	4, 8, 12A, 12B
NWB	1.1, 3.1, 4.1, 5.1	1.2, 3.2, 4.2, 5.2	1.3, 3.3, 4.3, 5.3	1.4, 3.4, 4.4, 5.4
NWB	1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 6.2, 6.3, 7.1	1.2, 2.2, 2.2, 4.2, 5.2, 6.4, 6.5, 6.6, 7.2	1.3, 2.3, 2.3, 4.3, 5.3, 6.7, 6.8, 6.9, 7.3	1.4, 2.4, 2.4, 4.4, 5.4, 6.10, 6.11, 6.12, 7.4

It was decided that the samples should be conditioned to a known moisture content level as a way to eliminate at least one variable when dealing with a material as variable as wood. Two moisture contents, 40% and 20%, were chosen to represent different conditions on site. Wood with higher moisture content is found in places where water accumulates and damage is likely. Wood with lower moisture content is more common throughout Virginia City, but decay can still occur.

The first step in attaining an even moisture content was to dry the samples. Using ASTM Standard D4442 as a guide, the samples were oven dried in a 60º C oven. After three days the oven temperature was increased to 100º C and then to 110 ºC. The ASTM standard requires that the material not exhibit a weight greater than 1% of the original weight for two consecutive 24-hour spanned periods. With the wood samples, the stopping point was not determined by weight but by calculated moisture content. When the calculated moisture content of the wood remained stable over three days, the sample was considered to have reached its dry weight.

The samples were next conditioned following ASTM Standard D4933. After drying, the samples were placed in airtight plastic containers and covered with warm tap water. Over several days, the pieces were weighed to determine water uptake. When a piece had reached its target weight +/-1%, it was removed from the water, and placed either in a plastic sample bag or wrapped in the three layers of plastic wrap. The pieces were then placed in to a high humidity environment in the form of a desiccator with the desiccant tray replaced with warm water. The relative humidity inside the chamber was between 90% and 100%. The samples were allowed to remain for at least three days to allow for water to equilibrate within the sample.

Treatment

Treatment closely followed AWPA Standard A3-95. The first step of treatment required making the appropriate solutions. Following manufacturers instructions a 15% DOT solution was created by adding 0.75 pounds or 340.19 grams of crystalline DOT to 0.5 gallons or 1.89 liters of warm tap water. The solution was stirred rigorously until all solid had dissolved. A 1:1 glycol borate solution was mixed in a 500mL beaker, by putting 200mL of water and adding glycol borate until the level of liquid reached 400mL. This mixture was stirred vigorously until a consistent solution was obtained. 100% crystalline

DOT is available commercially as Tim-Bor Professional® from Rio Tinto Mineral or Nisus Corporation. DOT in glycol borates, which is DOT in a proprietary mixture of glycols including polyethylene glycol, is available commercially as Bora-Care® from Nisus Corporation. DOT in water will refer to the Tim-Bor solution and DOT in glycols will refer to the BoraCare solution.

Each sample was weighed before and after treatment in order to determine borate uptake. Treatment was carried out by brush, using a disposable 1½ foam brush for application. Each borate solution was applied in such a way as to avoid run over to non-treated sides by attempting to leave a ¼ inch border between the treated area and the edge of the sample. This was done to avoid the solution wicking into the sample along the end grain, as it is generally accepted that this is the easiest route of penetration, but is usually discounted when studying penetration depth. Each sample was brushed with the appropriate solution and returned to the humidity chamber for one week. One piece of new board from each sample set was treated by dipping (NWL5.1, 5.2, 5.3, and 5.4) for the edification of the researcher. The pieces were placed in the solution for three minutes, removed and wiped of excess solution.

The testing schedule ran Thursday through Wednesday, with treatment on February 21, 2008. Appendix B contains select photographs of the sample sets on treatment and testing days.

Testing

The Wednesday following initial treatment, one slice was removed from each sample for testing. For the logs both new and historic, the cut was made perpendicular to the grain, and made generously to create an allowance for any end grain penetration. The new boards were cut perpendicular to the longest edge and the slices were generally 3/8 to ½ inch in thickness. Half the slices were removed with cuts perpendicular to the longest edge and half parallel. The different methods of cutting the boards will allow for a comparison of penetration with respect to wood morphology, such that tangential and radial penetration depths could be compared. The sample slices were labeled with pencil with the sample number and “Week 1.” They were then left to air dry for 24 hours at which point testing began. After air drying, each sample was sanded to reduce cross-contamination from cutting. The pieces were then cleaned using compressed air to remove all sawdust.

The reagents needed for testing were created following standards published by Nisus Corp. 0.60grams of curcumin were dissolved in approximately 200mL of warm ethanol and then enough ethanol was added to created a 500ml solution. 30grams of salicylic acid were dissolved in 100mL of concentrated hydrochloric acid (37% w/v) and then ethanol was added to create a 500mL solution. A portion of each solution was then transferred to a plastic spray bottle.

The samples were laid out and sprayed with the curcumin reagent such that they were wet but liquid was not running off. After 3-5 minutes of drying time, the salicylic acid reagent was sprayed on the samples. After a twenty minute time lapse, the penetration depth of the samples was noted and measured.

The boundary of the color change was first marked with a pencil and lines drawn where the measurement would be taken. Using a Fisher Scientific Digital Caliper, the length of the colored portion of the sample, which corresponds to penetration depth, was measured. For the boards, four measurement were taken along the treated side. For the logs, at least four measurement were taken, usually more, as the many checks in the wood created opportunities for measurement deeper into the sample.

This testing process was repeated six times on a weekly basis, starting February 21 and concluding on April 1. For each sample, the dimensions were recorded and for each measurement, depth, location (edge or check), penetration direction (tangential, radial, or a combination), and week number were recorded. Appendix A, Table 1 contains the raw data gathered from the experiment. Tangential penetration corresponds to movement parallel to the grain and radial penetration is movement perpendicular to the grain. Some measurement sights do not have a clear direction and were classified as a combination.

Differences With Industry Practice

Testing carried out for this thesis follows closely with the general spirit of industry testing, but must be conditioned for cultural resource management as opposed to forest resource management. The most obvious difference is with sample procurement. Industry tests aim for homogeneity within their sample set by using large sets of store-bought lumber, milled to standard shapes and sizes. The very nature of the experiment removes some control over the nature of collected samples, i.e. what can be removed from a historic site.

Additionally, there is generally no limit to the size of the sample set used in industry experiments, with some researchers using sample set containing hundreds of samples. Use of large sample sets is preferred for a material such as wood where large inconsistencies exist not only between samples of the same species but even within a single sample. Subdividing the available pieces of wood into smaller samples may not entirely make up for having a relatively small sample set, but any increase will yield more data points which will help compensate for discrepancies caused by inconsistencies in the wood.

Another major difference comes from the way in which the treatments were applied to the samples. In industry practice, much of the experimentation is geared towards wood not yet in service and is therefore treated in such a way to mimic factory treatment where every exposed surface of the wood is treated, either by spray or dipping. However, in the field of historic preservation, the treatments are most often remedial and must be carried out *in situ*. For this reason, treatment was applied to one face by brush in order to mimic conditions likely to be found during an actual treatment, where only one side of the wood may be exposed and available for treatment.

Actual testing differs very little from industry practice. There are other tests available for determining the concentration of borates within a sample and while these tests produce more accurate results about penetration and concentration, they are not feasible for a 4-month study with limited funding. The curcumin/salicylic acid test has it's limitations, namely that it only detects boric acid equivalent concentrations above 0.15-0.20%, while 0.10%BAE is considered effective against most wood destroying pests (Schoeman 1998). This will be taken into account during the analysis of the data.

Observations

Treatment Day

The samples conditioned to 20% MC appeared to have trouble absorbing the DOT and water solution. Especially on the new wood boards, the solution would often bead up until brushed not quite vigorously, but brushed hard enough to break the surface tension between the wood and the solution, at which point the treated surface would become obviously wetted. The same effect was noted on the wood conditioned to 40% MC, but not nearly as pronounced. Samples 5.1, 5.2, 5.3, and 5.4 were treated by dipping and again, the borate solutions appeared to have trouble wetting the surface tension on wood conditioned to 20% (samples 5.1 and 5.2) and to a less extent those treated to 40% MC (samples 5.3 and 5.4). Some agitation with the application brush seemed necessary to break the surface tension.

The method of experimentation attempted to avoid wicking through the end grain by leaving a ¼" untreated edge along the sides of each sample. This method proved sufficient for most wood conditioned to 20%. Exceptions were the new logs, where abundant checking in the treated surface created opportunities for the solution to enter the wood, eventually moving to the end grain face of the sample.

It proved more difficult to control wicking on samples conditioned to 40%. On treatment day, the samples felt wet to the touch and no margin was sufficiently wide enough to prevent the solution from wicking to the edge and down the side. When the new boards samples were moved from their initial testing location to the humidity chamber, solution could be seen on the bottom of almost every sample. This was particularly prominent with those samples treated with DOT in glycols (sample set 4).

Week One Testing

The samples treated with DOT in water (sample sets 1 and 3) formed a white crystalline coating between treatment day and testing (figure 5.1). This is probably the disodium octaborate tetrahydrate crystallizing out of solution as the water was either pulled into the wood or evaporated from the surface. There is no visibly discernible difference in

Figure 5.1: HWB5 with white crystalline powder on surface at week 1 of testing.

the quality or quantity of the coating between different sample sets and different types of samples.

A slight yellowing has occurred on the new boards treated with both DOT in water and DOT in glycols. When cross section were taken, the yellowing was visible inside the wood as well and seemed to correspond to penetration of the solution. No yellowing was witnessed on the historic wood, but this may be due to the highly weathered, dark grey color of the surface, possibly obscuring any color change.

Mold Growth

By week one mold had flourished on the aged boards and to a lesser extent the historic logs in sample set 4 (DOT in glycol at 40%MC). Surfaces treated with DOT and glycol show no signs of mold growth. Borates are ineffective against mold , but ethylene glycol is known to have mild biocidal qualities of its own.

Mold growth continued over the weeks of testing, spreading to the all samples in sample set 4 and eventually taking over sample set 3 as well (DOT in glycol at 20%MC). However, surfaces treated with glycol remained mold free through the duration of the treatment, even in the face of abundant and varied mold on surrounding surfaces. Both sample sets treated with DOT in water remain unaffected by mold.

Checking and Capillary Action

Checking occurs as wood dries and the outside layer of the log dries faster than the interior, creating a stress. This stress is then relieved by a split along the grain. The phenomenon is restricted to the logs, both new and historic, as the boards did not contain noticeable checking. For the purposes of this study, checking is important as it provides pathways not only for deterioration but an opportunity for the ingress of preservatives as well. If fungal damage starts near the center of the log, decay may go unnoticed, increasing the chances of total destruction.

It is well understood that water will rise higher in a capillary tube with a small diameter as compared to a larger diameter. While the parallel between a capillary tube and a check in wood is not exact, the concept is nevertheless apparent in the samples. During treatment, both types of solution were observed straddling wide checks in the wood, capillary action too weak to overcome surface tension in the solutions. When the first cross-sections where taken from the logs, a clear relationship between check size and totality of penetration emerged. The smallest checks, some not even noticeable until the section was taken and the testing carried out, proved most effective at pulling the solutions, both water- and glycol-based, into the checks. Larger checks, those wider than 1mm were not as effective, showing only a shallow borate penetration.

One major check in the new log extends nearly to the central growth rings. This check is about 2.5mm across and no penetration of solution was observed within it. Several smaller checks are present as well, and for the most part checks with a diameter less than 1.0mm exhibited near total penetration along the entire depth of the check. Some exceptions are present, but it may be due the fact that the check existed only in potential at the time of treatment and the crack manifested after a thin slice was removed from the larger sample and rapidly dried (figure 5.2).

Patterns of Penetration

In the historic logs treated with DOT in glycol at 40% MC (sample set 4), there appears to be a line of demarcation at one of the growth rings where the penetration stops. This is likely the line between heartwood and sapwood. Heartwood is dead wood at the center of the tree and sapwood is the living, actively growing outer shell. Sapwood eventually becomes heartwood as the tree grows, and waste products are deposited in the dead cells. The waste

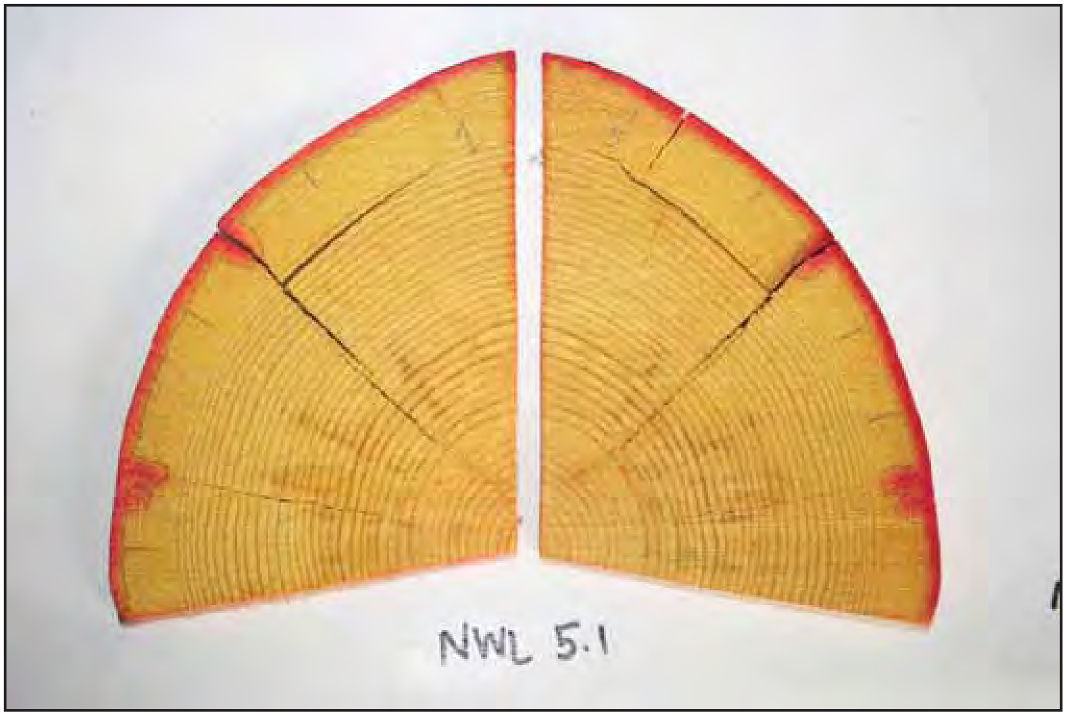


Figure 5.2: NWL5.1 showing treated and untreated checks at week 6. The thinner checks show greater penetration than the larger checks.

products are often toxic to insects and fungi, making heartwood of some species very decay resistant. Unfortunately, pine is not in this category and lodgepole pine is considered a non-durable species (Richardson 1976). Toxic or not, the presence of waste material could be an obstruction to diffusion.

The boundary of penetration in the historic log from sample set 4 is not dependent on distance from the surface, but appears to be directly tied to the line between the heartwood and sapwood. Week one testing of the historic logs treated with DOT in glycols (sample set 4) revealed a varied penetration depth, but this is due to the fact that the log is chamfered on one side. The penetration along the flat edge behaves as if the log was whole, penetrating only to the line between heartwood and sapwood (figure 5.3). In the following weeks of testing, borates penetrated beyond this line into the heartwood, but the intensity of the colorimetric testing was far less than the sapwood (figure 5.4).

Several of the historic boards cut to show tangential penetration exhibit a lack of borates on the treated edge. Pieces cut to show radial penetration do not show this same feature.

Figure 5.3: HWL4, week 1 testing. The line of penetration is very clear.

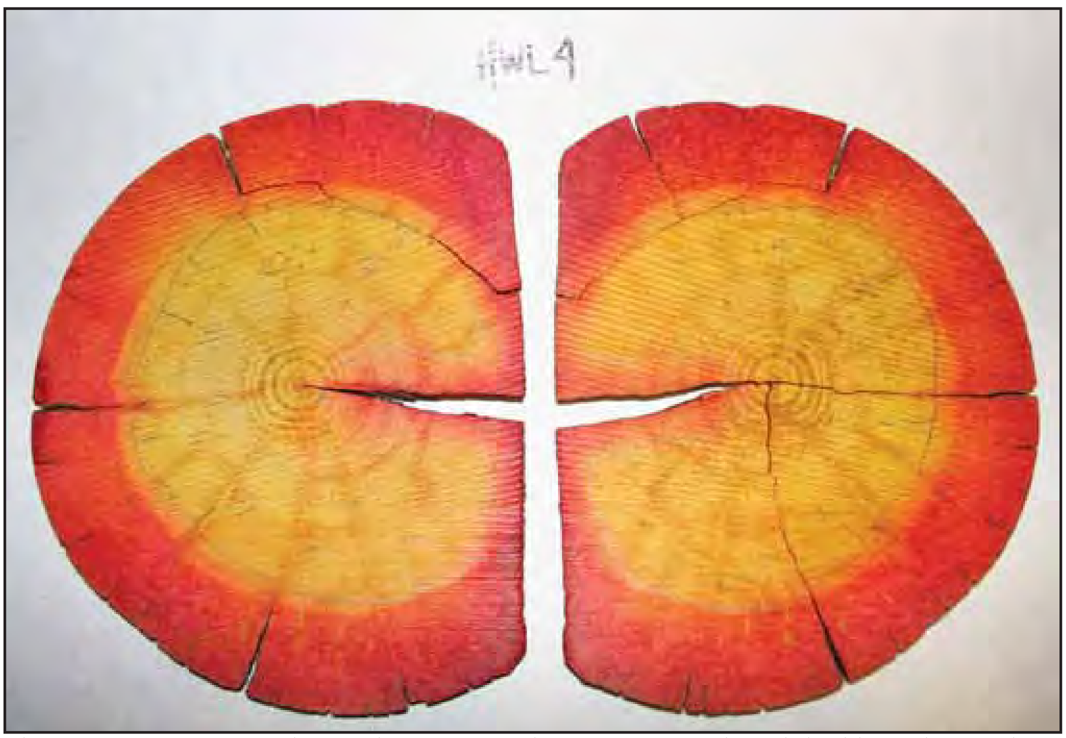


Figure 5.4: HWL4, week 6 testing. Penetration moves past the original boundary and diffuses past the sapwood/heartwood boundary.

The phenomenon is not specific to DOT in water or glycols and became more pronounced as testing progressed (figure 5.5).

Figure 5.5: HWB7, week 6 testing, showing borate loss along the treated edges.

Viewing the historic boards under the microscope, the borates seem to concentrate in the late-wood portion of the growth ring, creating a ridged indication pattern near the treated edge (figure 5.6). Additionally, the curcumin-salicylic acid reagent test showed a deeper color in the latewood section of the growth rings in all types of wood. Examination under the microscope of several new log samples showed that the curcumin reagent had seeped through to the untested side, but only along the latewood portion of the growth ring (figure 5.7). The areas of seepage showed no signs of being compromised by cracks, and it is therefore assumed that the reagent solution was able to penetrate the section through the late wood.

Generally, the borate solution penetrated evenly in the new boards, yielding a boundary

Figure 5.6: Micrograph of HWL4, week 6, showing the accumulation of borates in the latewood and the resultant ridged pattern along the treated edge.

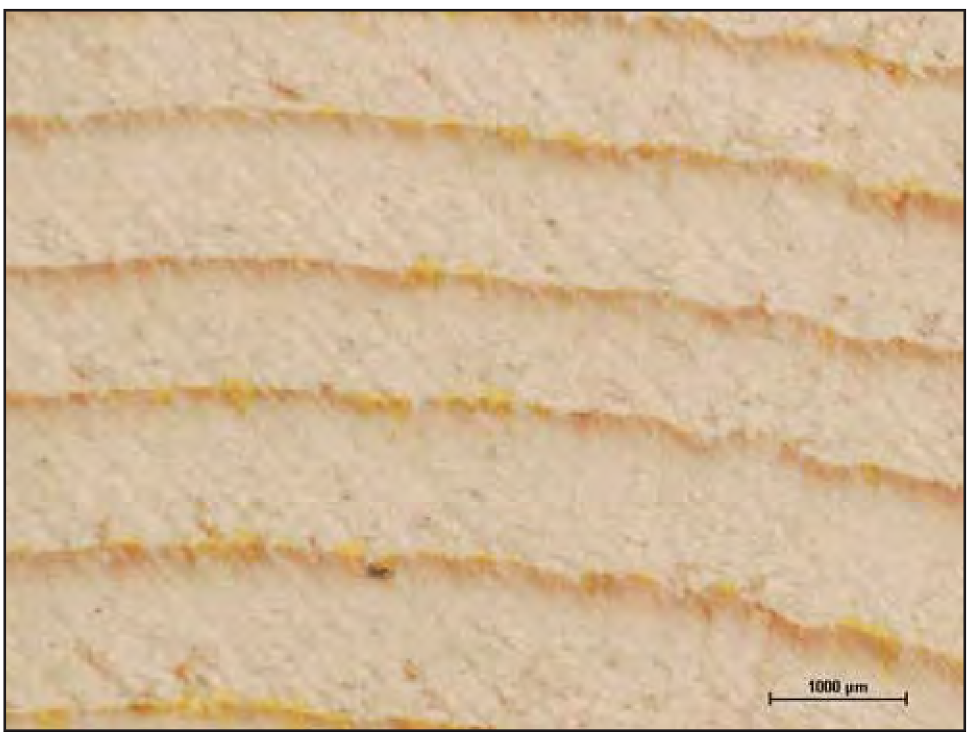


Figure 5.7: Micrograph of NWL1.2, week 6, showing the curcumin reagent seeping through to the untested side through the latewood section of the growth ring.

that closely paralleled the treated surface, regardless of treatment type (figure 5.8). In new logs treated with DOT in water, the same is true, but in those new logs treated with DOT in glycol, the boundary line is highly irregular and appears to bear no relation to existing checks and other surface irregularities (figures 5.9, 5.10). The historic logs treated with DOT in water also exhibit treatment boundaries that closely parallel the surface. In historic logs treated with DOT in glycols at 20%MC, the boundary again parallels the surface, dipping further into the wood where checks exist, but the depth of penetration does not reach the sapwood-heartwood divide (figure 5.11). In the historic log treated with DOT in glycols at 40%MC, there is total penetration to the same divide and from there, penetration continues in an even fashion (figure 5.4).

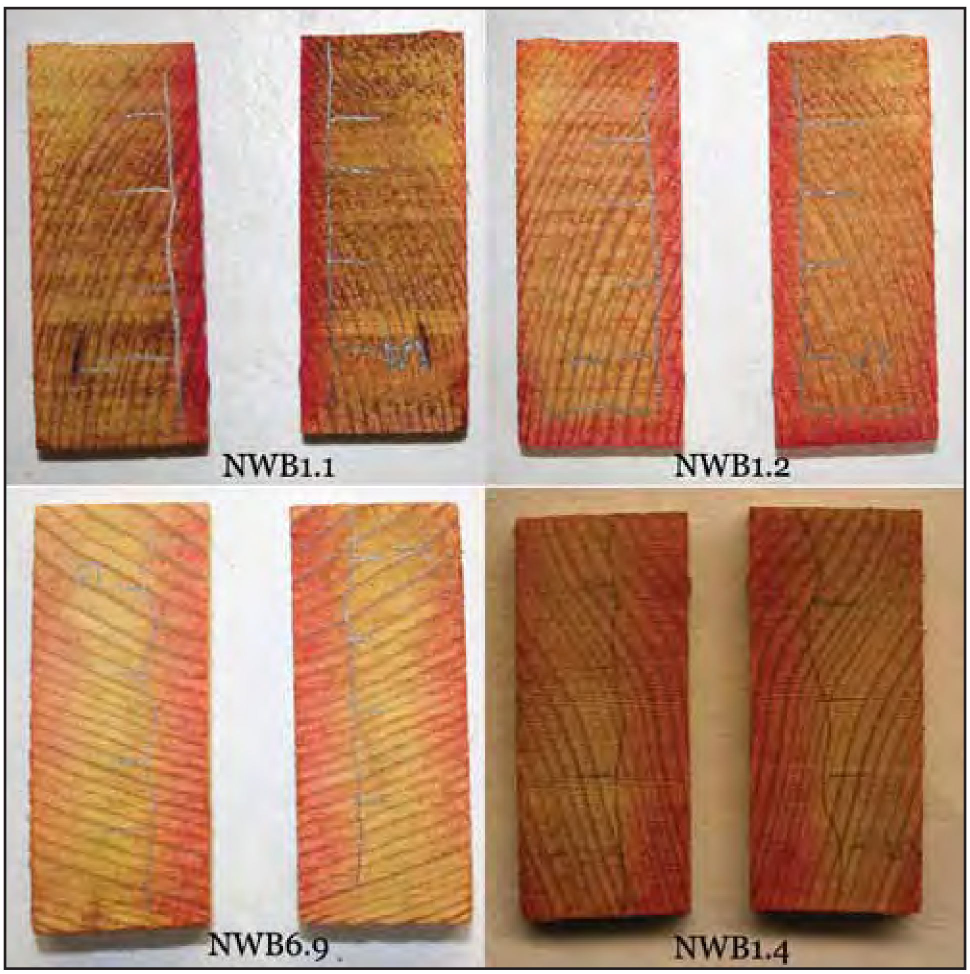


Figure 5.8: Various NWB showing even penetration in relation to the surface.

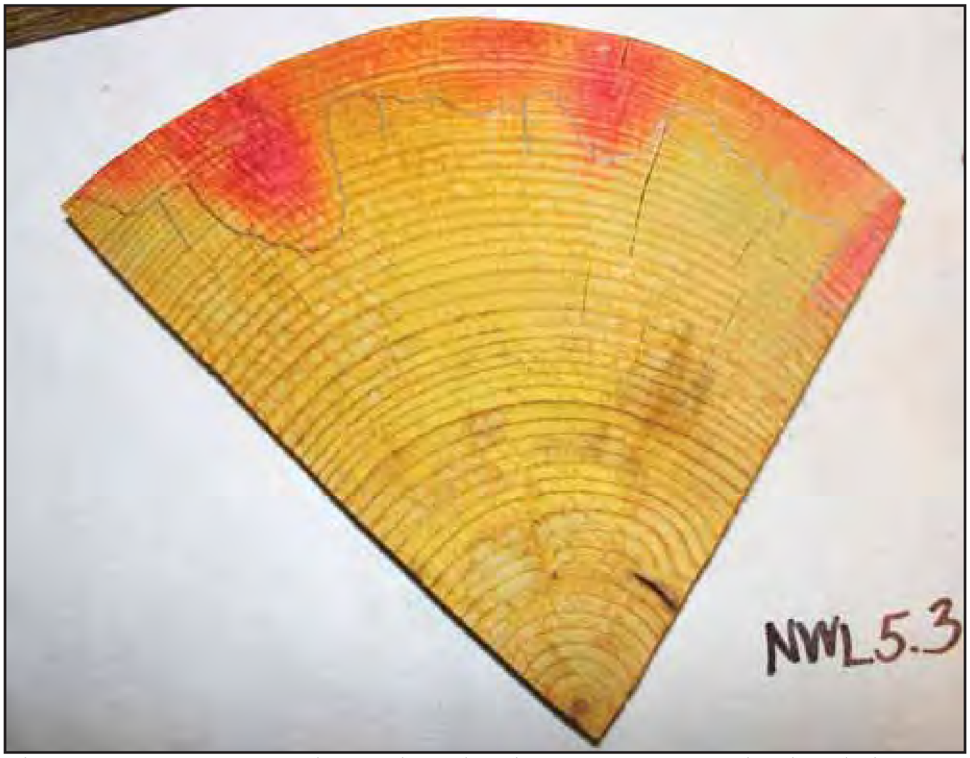


Figure 5.9: NWL5.3, week 3 testing, showing uneven penetration in relation to the surface.

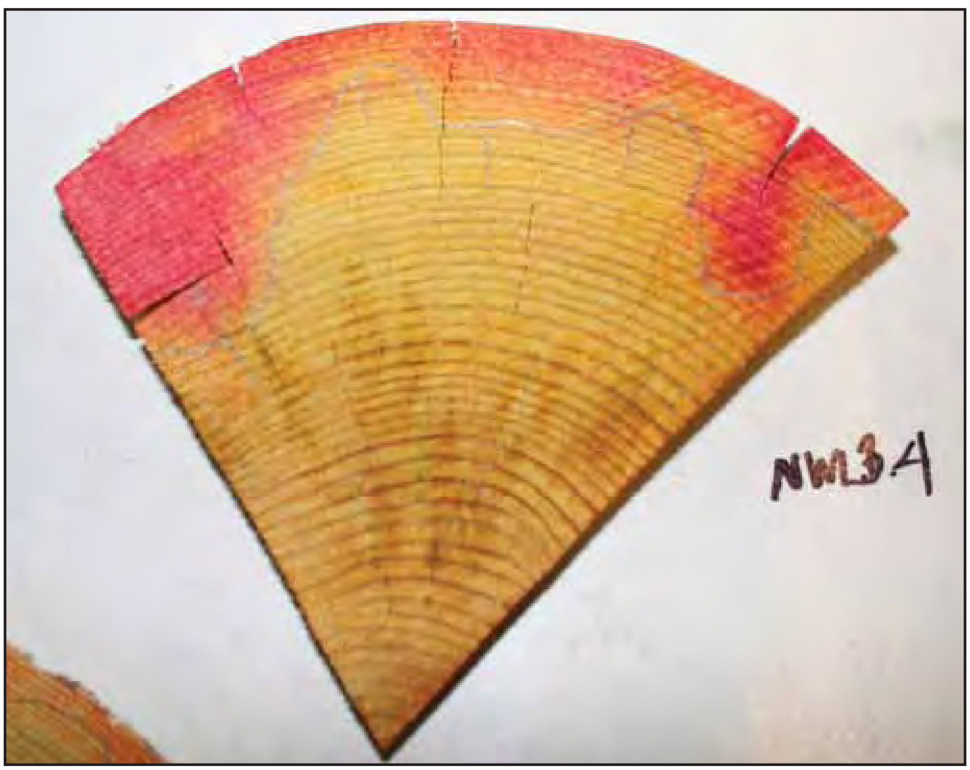


Figure 5.10: NWL3.4, week 3 testing, showing uneven penetration in relation to the surface.

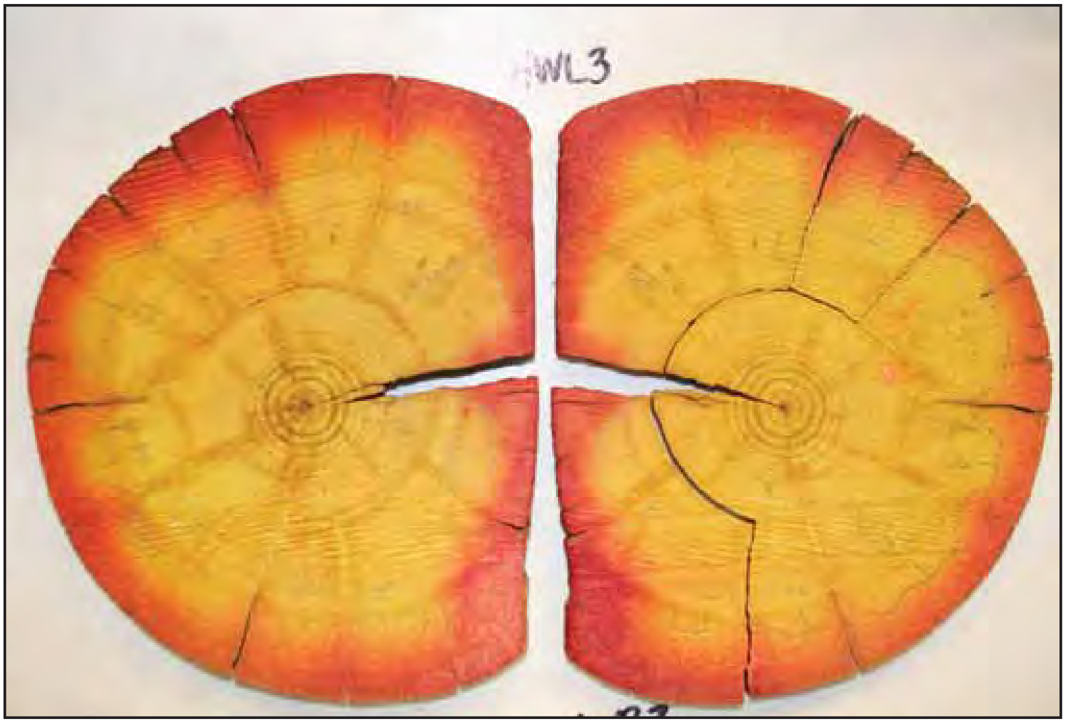


Figure 5.11: HWL3, week 6 testing, showing even borate penetration in relation to the treated edges.

Analysis

After six weeks of testing, the collected data was subjected to statistical analysis in hopes of teasing out further information regarding the behavior of borates in historic lodgepole pine. In additional to the statistical analysis, comparison of values between different sample sets were made to understand further the way in which borates in solution behave in lodgepole pine.

Data Integrity

By employing the interquartile range (IQR), outliers in the data set were identified and removed. IQR first divides the data set in half according to the median. The half sets are then subdivided by their respective medians, yielding a data set divided into quartiles. Q1 is the median of the first half of the data set and Q3 the median for the second half. The IQR is the difference between Q1 and Q3. Any data that is

greater than Q3 + 1.5IQR

or less than Q1 – 1.5IQR

can be discarded from analysis as it can be considered an extreme value (Donnelly 2007).

Using the QUARTILE function in Microsoft Excel, the IQR standard was applied to all data gathered and outliers discarded. In Appendix A Table 1 contains all raw data and Table 2 contains a complete list of outliers. With a clean set of data in hand, analysis could proceed.

Data Analysis Methodology

In Microsoft Access, a query was written to calculate the weekly average penetration depth as grouped by wood type, wood age, treatment type, and moisture content. This query yielded 96 averages, and Table 6.1 contains this basic information. Instead of relying on visual comparison in graphs or strict comparison of numbers, a statistical test was employed to determine if the differences between the averages were statistically significant. The statistical analysis was carried out only on data from the final week (week 6) of testing, as the end result is the most important and the set used most heavily for drawing conclusions.

The test employed is known as the Student's t-test, so named as it was published anonymously under the name "Student" by William Gossett in 1908. The t-test allows for comparison of two sample groups with different means and unequal variances in order to confirm or refute the existence of a statistical difference. The mean describes the average value within a data set and the variance characterizes the distribution of the data in relation the mean.

The t-test begins by setting a null hypothesis, denoted as $H_{0,}$ and is generally set where the mean of the first sample is less than or equal to the mean of the second. An additional hypothesis, H_1, states that the opposite is true, or that the means of the first sample set is greater than the second, and is denoted as follows:

$$H_0 : \mu_1 \leq \mu_2$$

$$H_1 : \mu_1 > \mu_2$$

Table 6.1: Weekly Penetration Depth Averages

Sample Set	Treatment Vehicle	Moisture Content	Wood Type	Wood Age	Week	AvgOfResult
1	Water	20%	Boards	Historic	1	2.78
					2	3.55
					3	3.20
					4	3.64
					5	4.07
					6	4.27
				New	1	2.51
					2	3.43
					3	3.45
					4	4.12
					5	4.31
					6	4.52
			Log	Historic	1	4.66
					2	5.23
					3	6.64
					4	6.93
					5	7.74
					6	7.43
				New	1	2.11
					2	2.89
					3	2.81
					4	3.20
					5	3.75
					6	4.00
2	Water	40%	Boards	Historic	1	3.36
					2	3.97
					3	4.65
					4	4.06
					5	5.24
					6	5.57
				New	1	2.95
					2	3.33
					3	3.64
					4	4.38
					5	4.74
					6	4.95
			Logs	Historic	1	3.16
					2	4.45
					3	5.71
					4	5.69
					5	7.21
					6	7.29
				New	1	3.71
					2	4.24
					3	4.62
					4	5.18
					5	5.86
					6	6.13

Table 6.1: Weekly Penetration Depth Averages, continued

Sample Set	Treatment Vehicle	Moisture Content	Wood Type	Wood Age	Week	AvgOfResult
3	Glycols	20%	Boards	Historic	1	6.45
					2	10.89
					3	9.41
					4	7.40
					5	9.05
					6	8.88
				New	1	5.82
					2	6.96
					3	7.45
					4	7.40
					5	9.02
					6	9.00
			Logs	Historic	1	18.45
					2	7.94
					3	11.15
					4	13.63
					5	14.59
					6	16.06
				New	1	13.70
					2	8.42
					3	10.64
					4	10.78
					5	12.97
					6	13.16
4	Glycols	40%	Boards	Historic	1	4.89
					2	6.69
					3	7.33
					4	7.75
					5	7.91
					6	9.42
				New	1	4.65
					2	6.27
					3	7.21
					4	7.55
					5	8.79
					6	9.95
			Logs	Historic	1	26.69
					2	29.46
					3	28.88
					4	28.58
					5	28.65
					6	30.62
				New	1	15.31
					2	12.85
					3	11.33
					4	10.78
					5	14.65
					6	15.34

Where:

μ_1 = mean of the first sample set

μ_2 = mean of the second sample set.

For the purpose of the thesis many comparison were made, and the value of μ_1 and μ_2 change with each a comparison.

Two numbers are necessary to draw conclusions from the t-test. The calculated t-score is dependent on the standard error of difference between the two means and the difference between the two means. The equations are as follows:

The t-score is calculated with the following equation:

$$t - score = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)_{H_0}}{\sigma_{\bar{x}_1 - \bar{x}_2}}$$

Where:

$\bar{x}_1$ and $\bar{x}_2$ are the sample means and

$(\mu_1 - \mu_2)_{H_0}$ is the null equation, and the value is zero.

$$\sigma_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

s is the standard deviation of the sample set and,

n is the number of data points in each set.

The second number is the degrees of freedom (d.f.). This number is necessary to determine the critical t-score, which is obtained from published charts specifically for the Student's t-test. The equation for d.f. is as follows:

$$d.f. = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}}$$

If the t-score is less than the critical t-score, H_0 can be accepted, but if the t-score is greater than the critical t-score, H_0 is rejected and H_1 accepted.

Fortunately for the researcher Microsoft Excel has a Data Analysis tool for several different t-tests. Table 3 in Appendix A contains the Excel data for the calculated t-scores. Each set of comparisons takes into account a different factor separately. These factors are moisture content (20% or 40%), DOT vehicle (water or glycols), wood type (board or log), and wood age (historic or new). The t-test confirms that there is a statistical difference between all comparisons.

Analysis

Determining Significant Levels of Penetration

With the knowledge that all comparison are statistically different, the question becomes one of actual significance when translated into penetration depth. Tables 6.2-6.5 summarize the penetration depth for all samples grouped in such a way to reflect comparisons between different factors. A cursory view shows that often the differences within the comparison sets are quite small, sometimes less than 0.25mm.

In most writing on the subject, deeper equals better, but the results given seem relative, with no real discussion of why one depth is better than the other. Penetration depth graphs are often on the millimeter scale with a range of only a few millimeters, exaggerating the actual difference between samples. A study by Schoeman concludes that differences in penetration depth of only 2mm are considered significant, but fails to say why (1998). Other studies give penetration depth as a percentage of the piece of wood (Freitag 2002). For the purpose of this thesis, percentage of penetration related to entire width is not particularly relevant, as the sample width varies between the wood types, and so strict depth of penetration will be considered.

The question remains however, what classifies a difference as substantial. Effective penetration depths are ones that prevent decay from starting. In the case of fungal decay, efficacy of borates means prevention of fungal spore germination and for wood-boring insects, this translates to prevention of egg deposition or hatching. The starting point for both fungal deterioration and wood-boring insect attack are microscopic.

Fungal spores landing on the surface of wood will stay on the surface, as they lack any active means to transport themselves into the interior. The spores may gain access to deeper places in the material through cracks and fissures via water transport, but where a 10μm fungal spore can go, so goes a water soluble compound (Willets 1969).

While the exact species of wood-boring insect ravaging Virginia City is unknown, beetles have the same basic anatomy across the board. A female beetle uses her ovipositor to insert eggs into a desired location, and in the case of wood boring insects, this location is inside the pores of wood. Insects in the family *Lyctidae* have been shown to have ovipositors that can extend further than the length of the body, which is anywhere from 3mm to 6mm (Parkin 1934). Parkin states that eggs are laid "some distance from the surface" without providing actual numbers. This is some cause of concern for the researcher, since an egg 6mm from the surface may very well be out of the range of borate penetration. However, a female beetle is not without maternal instincts, and research has shown that the insects will probe wood for suitability before laying eggs (Rosel 1969). If the insects are capable of assessing the quality of wood as food based on the presence of protein and starch, they are likely just as capable of detecting the presence of chemicals deadly to their offspring. Creffield's research showed that a single brush application of borates in glycols was sufficient to prevent powderpost beetle infestation, although the article came to this conclusion based on lack of emergence holes and did not specify whether eggs were laid and failed to hatch or simply not laid (1983).

Based on this information it is the opinion of the researcher that for the purposes of deterioration prevention, the consistency of an intact exterior shell of borate-protected wood is the key to efficacy. As such any difference in penetration depth is meaningful and determining significance returns to statistics.

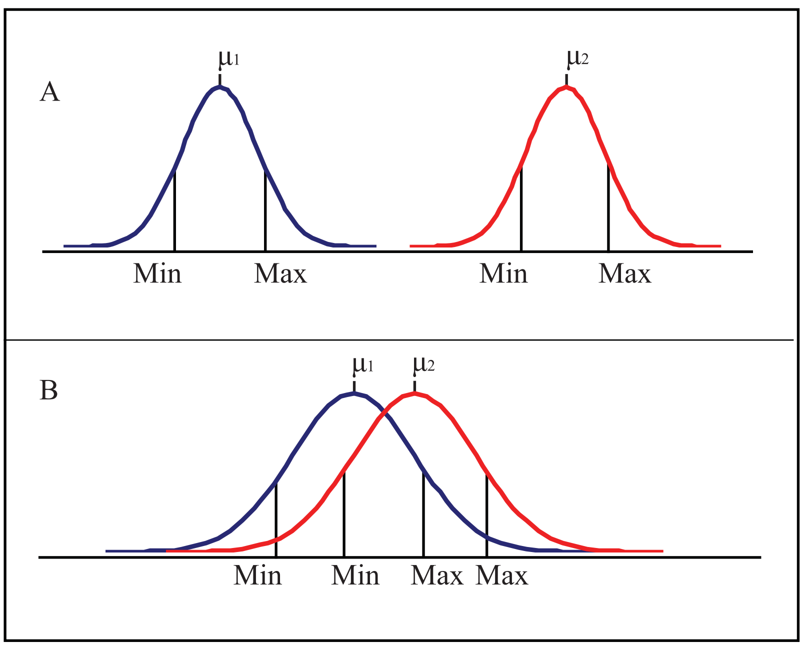


Illustration 6.1: Visual representation of the margin of error min-max test. In section A, the minimum value of sample set 2 is greater than the maximum value of sample set 1 and the comparison holds true. In section B, the minimum value of sample set 2 is less than the maximum value of sample set 1, and therefor, the comparison is discarded as statistically invalid.

A confidence interval for a set of data gives a value range where the upper and lower limits are likely to include any piece of data. The confidence interval is calculated as follows:

$$\sigma_{\bar{x}} = \bar{x} + z_c \sigma_{\bar{x}} \text{ (upper limit of confidence interval)}$$

$$\sigma_{\bar{x}} = \bar{x} + z_c \sigma_{\bar{x}} \text{ (lower limit of confidence interval)}$$

where:

$\bar{x}$ = the sample mean

z_c = the critical z-score, which is the number of standard deviations based on the confidence level

$\sigma_{\bar{x}}$ = the standard error of mean.

The standard error of mean, $\sigma_{\bar{x}}$, is determined by the equation:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

where:

n = sample number

σ = standard deviation for the data set.

The confidence interval was calculated in Microsoft Excel using the CONFIDENCE function, which uses the above equation to calculate $z_c \sigma_{\bar{x}}$, known as the margin of error. Further calculations supplied the upper and lower limits of the confidence interval. In the calculation, the critical z-score was set at 1.96, which is the value necessary for a 95% confidence interval. When looking at comparisons, if the minimum limit value of the higher penetration depth remained higher than the maximum limit of the lower penetration depth, the comparison is considered to hold true. This concept is illustrated visually in Illustration 6.1. This methodology eliminates only a handful of comparisons, and these values are highlighted red in the tables 6.2-6.5. Values highlighted in yellow are the higher value in the comparison set.

Moisture Content

This comparison group takes into consideration moisture content only. That is, of the four variable tested, only moisture content is different between the two sample sets in each comparison. Generally, the initial moisture content of the sample made marginal difference in the end result for depth of penetration, but for the comparisons that passed the margin of error min-max test, samples with a higher moisture content yielded deeper penetration. This statement is made with reservations—of the five comparisons taken in to consideration, two have differences less that 0.5mm, a piddling difference, leaving only three sets with which to draw conclusions. (See Table 6.2)

While every effort was made to simulate real world conditions during experimentation, certain compromises had to be made in order to simplify the experiment and reduce the number of variables. Most noticeably was the strict control of moisture content in the wood samples. In Virginia City, most in service wood has a moisture content around 12%, well below the tested levels of 20% and 40%MC, as revealed by a cursory investigation with a handheld protimeter.

With only two points of data, it is difficult to hypothesize about penetration depth in wood at very low moisture content, because the exact nature of the relationship between moisture content and depth of penetration is unclear in this experiment. However, a study by Schoeman concludes that penetration depth is affected by moisture content at values above 15%MC, with higher MCs leading to deeper penetration (1998). Below 15%MC, penetration depths are not greatly affected, and are quite shallow, rarely above 2mm. For wood in service at Virginia City, it is possible that penetration depths achieved in dry *in situ*

Table 6.2: Moisture Content Comparison: 20%MC vs. 40%MC

Sample Set	Comparison: Moisture Content	Treatment Uptake (g)	Week 1 Penetration (mm)	Week 6 Penetration (mm)	Difference (mm)	Margin of Error	Min	Max	Min/Max Difference	% Penetration in First Week
1	Historic Boards_20%MC and DOTw/Water	2.4	2.78	4.27	1.30	0.21	4.06	4.48	0.81	65%
2	Historic Boards_40%MC and DOTw/water	2.60	3.36	5.57		0.28	5.29	5.85		60%
3	Historic Boards_20%MC DOTw/glycols	2.30	6.45	8.88	0.54	0.62	8.26	9.50	-0.61	73%
4	Historic Boards_40%MC DOTw/glycols	2.73	4.89	9.42		0.52	8.90	9.94		52%
1	Historic Log_20%MC and DOTw/Water	12.17	4.66	7.43	-0.14	1.27	6.16	8.70	-1.86	63%
2	Historic Log_40%MC and DOTw/water	14.06	3.16	7.29		0.45	6.84	7.74		43%
3	Historic Log_20%MC DOTw/glycols	11.13	7.94	16.06	14.56	1.29	14.77	17.35	12.09	49%
4	Historic Log_40%MC DOTw/glycols	7.21	26.69	30.62		1.18	29.44	31.80		87%
1	New Board_20%MC and DOTw/Water	0.77	2.51	4.52	0.43	0.12	4.40	4.64	0.18	56%
2	New Board_40%MC and DOTw/water	1.15	2.95	4.95		0.13	4.82	5.08		60%
3	New Board_20%MC DOTw/glycols	0.87	5.82	9.00	0.96	0.23	8.77	9.23	0.46	65%
4	New Board_40%MC DOTw/glycols	1.15	4.73	9.96		0.26	9.70	10.22		47%
1	New Log_20%MC and DOTw/Water	1.65	2.11	4.00	2.14	0.16	3.83	4.16	1.78	53%
2	New Log_40%MC and DOTw/water	1.93	3.71	6.13		0.20	5.94	6.33		60%
3	New Log_20%MC DOTw/glycols	1.52	8.42	13.16	2.27	0.94	12.22	14.09	-0.14	64%
4	New Log_40%MC DOTw/glycols	2.09	12.99	15.43		1.47	13.96	16.90		84%

wood may not be much lower than depths witnessed in samples with 20%MC.

Treatment Type

The next comparison group pits DOT in water against DOT in glycols, and with this comparison group, the results are very clear. In every instance, even after the margin of error min-max test, the samples treated with DOT in glycols yielded higher penetration results than those treated with DOT in water. (See Table 6.3)

Wood Type

The third comparison group isolates wood type, contrasting boards against logs. In all but one comparison, the logs fared better than boards. In the one exception, (sample set 1, treated with DOT in water at 20%MC), the adjusted difference in end penetration was only 0.24mm. While it did pass the margin of error min-max test, the difference is too close for comfort for the researcher to accept. The results of this comparison are particularly confusing, as it is generally accepted that rougher surfaces lead to greater penetration as a result of increased surface area (Archer 1990). The boards, both historic and new, were rougher than the logs.

The historic board has been exposed to the elements since 1863, and as such, the surface is very ridged, as compared to the surface of the historic log, which has lived a sheltered life inside the wall of the McGovern Building. Even after 144 years in service, the surface of the aged log remains relatively smooth. The same surface roughness variation applies to the new boards and logs, but for different reasons. The new boards are rough sawn at the mill and minimal finishing is done to the lumber before it is incorporated into a repair. The log sample was stripped of its bark with a draw knife, leaving a smooth surface as compared to the boards. The only hypothesis is that the more exposed life of the historic boards led to the paths of penetration being compromised. (See Table 6.4)

Table 6.3: Treatment Type Comparison: Water vs. Glycols

Sample Set	Comparison: Treatment	Treatment Uptake (g)	Week 1 Penetration (mm)	Week 6 Penetration (mm)	Difference (mm)	Margin of Error	Min	Max	Min/Max Difference	% Penetration in First Week
1	Historic Boards_20%MC and DOTw/Water	2.4	2.78	4.27	4.61	0.21	4.06	4.48	3.78	65%
3	Historic Boards_20%MC DOTw/glycols	2.30	6.45	8.88		0.62	8.26	9.50		73%
2	Historic Boards_40%MC and DOTw/water	2.60	3.36	5.57	3.85	0.28	5.29	5.85	3.05	60%
4	Historic Boards_40%MC DOTw/glycols	2.73	4.89	9.42		0.52	8.90	9.94		52%
1	Historic Log_20%MC and DOTw/Water	12.17	4.66	7.43	8.63	1.27	6.16	8.70	6.07	63%
3	Historic Log_20%MC DOTw/glycols	11.13	7.94	16.06		1.29	14.77	17.35		49%
2	Historic Log_40%MC and DOTw/water	14.06	3.16	7.29	23.33	0.45	6.84	7.74	21.70	43%
4	Historic Log_40%MC DOTw/glycols	7.21	26.69	30.62		1.18	29.44	31.80		87%
1	New Board_20%MC and DOTw/Water	0.77	2.51	4.52	4.48	0.12	4.40	4.64	4.13	56%
3	New Board_20%MC DOTw/glycols	0.87	6.68	9		0.23	8.77	9.23		74%
2	New Board_40%MC and DOTw/water	1.15	2.95	4.95	5.01	0.13	4.82	5.08	4.62	60%
4	New Board_40%MC DOTw/glycols	1.15	4.73	9.96		0.26	9.70	10.22		47%
1	New Log_20%MC and DOTw/Water	1.65	2.11	4.00	9.16	0.16	3.83	4.16	8.06	53%
3	New Log_20%MC DOTw/glycols	1.52	8.42	13.16		0.94	12.22	14.10		64%
2	New Log_40%MC and DOTw/water	1.93	3.71	6.13	9.30	0.20	5.93	6.33	7.63	61%
4	New Log_40%MC DOTw/glycols	2.09	12.99	15.43		1.47	13.96	16.90		84%

Wood Age

The last comparison group looks at wood age, where it is revealed that age does not necessarily come before beauty. Only five of the eight comparison groups make the cut with regards to margin of error min-max test, and of these five, two samples fall outside the researchers comfort zone with differences less than 0.5mm, leaving only three sets with which to draw conclusions. In these three comparisons, historic samples yielded greater penetration depths than new samples, but this is not enough confirmation to make a broad statement about the age of wood and its affect on penetration.

However, all three surviving comparisons are logs, so it is the case that historic logs permit deeper penetration than new logs. During sample preparation, the historic logs were nearly sponge-like in their absorption of water, rapidly pulling in water, where the new logs were less eager in their uptake. Table 5 in Appendix A contains information on water uptake during the sample conditioning process.

Comparing new and historic boards, the numbers nearly support the hypothesis that new boards permit deeper penetration than old, but when applying the standard of error min-max test, the differences disappear. Unadjusted differences between new and old boards average 0.38mm while the min-max differences average 0.50mm. These differences are not enough to say conclusively that new boards permit deeper penetration than historic boards. (See Table 6.5)

Rate of Diffusion

Graphs 6.1 through 6.4 show penetration depth over time. While there is no clear rate for diffusion, what is obvious from the trend lines in the graphs is that there is a significant slowing of diffusion after six weeks. One of the principles of Fick's law of diffusion, a mathematical description of diffusion, states that there must be an adequate concentration within the diffusion volume for diffusion to continue. In the

Table 6.4: Wood Type Comparison: Board vs. Log

Sample Set	Comparison: Wood Type	Treatment Uptake (g)	Week 1 Penetration (mm)	Week 6 Penetration (mm)	Difference (mm)	Margin of Error	Min	Max	Min/Max Difference	% Penetration in First Week
1	Historic Boards_20%MC and DOTw/Water	2.4	2.78	4.27	4.61	0.21	4.06	4.48	1.68	65%
1	Historic Log_20%MC and DOTw/Water	12.17	4.66	7.43		1.27	6.16	8.70		63%
1	New Board_20%MC and DOTw/Water	0.77	2.51	4.52	3.85	0.12	4.40	4.64	0.24	56%
1	New Log_20%MC and DOTw/Water	1.65	2.11	4		0.16	3.84	4.16		53%
2	Historic Boards_40%MC and DOTw/water	2.60	3.36	5.57	8.63	0.28	5.29	5.85	0.99	60%
2	Historic Log_40%MC and DOTw/water	14.06	3.16	7.29		0.45	6.84	7.74		43%
2	New Board_40%MC and DOTw/water	1.15	2.95	4.95	23.33	0.13	4.82	5.08	0.85	60%
2	New Log_40%MC and DOTw/water	1.93	3.71	6.13		0.20	5.93	6.33		61%
3	Historic Boards_20%MC DOTw/glycols	2.30	6.45	8.88	4.48	0.62	8.26	9.50	5.27	73%
3	Historic Log_20%MC DOTw/glycols	11.13	7.94	16.06		1.29	14.77	17.35		49%
3	New Board_20%MC DOTw/glycols	0.87	6.68	9	5.01	0.23	8.77	9.23	2.99	74%
3	New Log_20%MC DOTw/glycols	1.52	8.42	13.16		0.94	12.22	14.10		64%
4	Historic Boards_40%MC DOTw/glycols	2.73	4.89	9.42	9.16	0.52	8.90	9.94	19.50	52%
4	Historic Log_40%MC DOTw/glycols	7.21	26.69	30.62		1.18	29.44	31.80		87%
4	New Board_40%MC DOTw/glycols	1.15	4.73	9.96	9.30	0.26	9.70	10.22	3.73	47%
4	New Log_40%MC DOTw/glycols	2.09	12.99	15.43		1.47	13.96	16.90		84%

Table 6.5: Wood Age Comparison: Historic vs. New

Sample Set	Comparison: Age	Treatment Uptake (g)	Week 1 Penetration (mm)	Week 6 Penetration (mm)	Difference (mm)	Margin of Error	Min	Max	Min/Max Difference	% Penetration in First Week
1	Historic Boards_20%MC and DOTw/Water	2.4	2.78	4.27	3.16	0.21	4.06	4.48	-0.08	65%
1	New Board_20%MC and DOTw/Water	0.77	2.51	4.52		0.12	4.40	4.64		56%
2	Historic Boards_40%MC and DOTw/water	2.60	3.36	5.57	-0.52	0.28	5.29	5.85	0.21	60%
2	New Board_40%MC and DOTw/water	1.15	2.95	4.95		0.13	4.82	5.08		60%
3	Historic Boards_20%MC DOTw/glycols	2.30	6.45	8.88	1.72	0.62	8.26	9.50	-0.73	73%
3	New Board_20%MC DOTw/glycols	0.87	6.68	9		0.23	8.77	9.23		74%
4	Historic Boards_40%MC DOTw/glycols	2.73	4.89	9.42	1.18	0.52	8.90	9.94	-0.25	52%
4	New Board_40%MC DOTw/glycols	1.15	4.73	9.96		0.26	9.70	10.22		47%
1	Historic Log_20%MC and DOTw/Water	12.17	4.66	7.43	7.18	1.27	6.16	8.70	2.00	63%
1	New Log_20%MC and DOTw/Water	1.65	2.11	4		0.16	3.84	4.16		53%
2	Historic Log_40%MC and DOTw/water	14.06	3.16	7.29	4.16	0.45	6.84	7.74	0.51	43%
2	New Log_40%MC and DOTw/water	1.93	3.71	6.13		0.20	5.93	6.33		61%
3	Historic Log_20%MC DOTw/glycols	11.13	7.94	16.06	21.2	1.29	14.77	17.35	0.67	49%
3	New Log_20%MC DOTw/glycols	1.52	8.42	13.16		0.94	12.22	14.10		64%
4	Historic Log_40%MC DOTw/glycols	7.21	26.69	30.62	5.47	1.18	29.44	31.80	12.54	87%
4	New Log_40%MC DOTw/glycols	2.09	12.99	15.43		1.47	13.96	16.90		84%

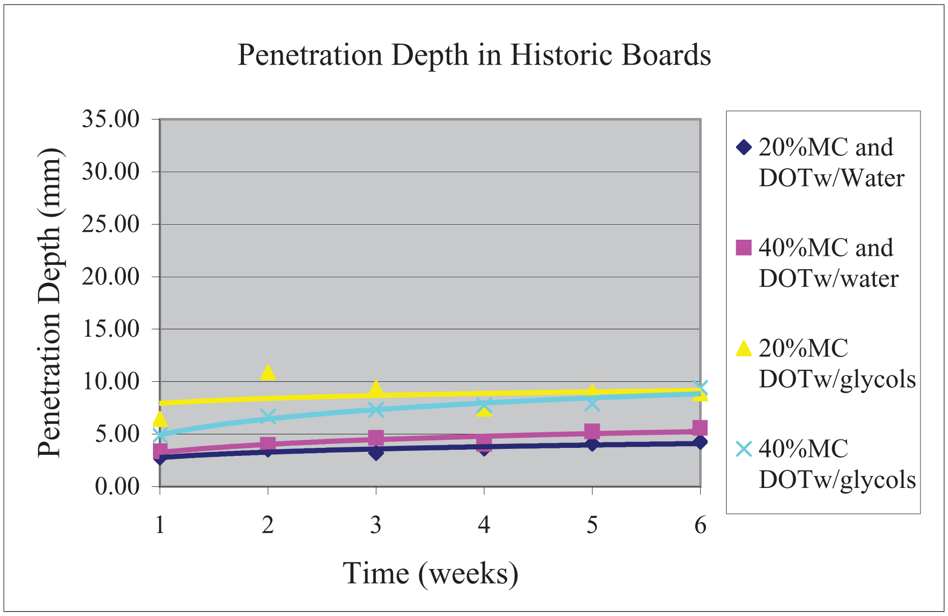
case of borate solution in treated wood, as time progresses, the solution concentration necessarily decreases as the solution moves into the wood. On average, 62% of all penetration was completed by the first week of testing. As such, the condition of the wood at the time of treatment would be very important to end penetration. For instance, if the wood was wetted prior to treatment, deeper penetration might be attainable.

Table 6.6: Comparison of NWB5 with all values.

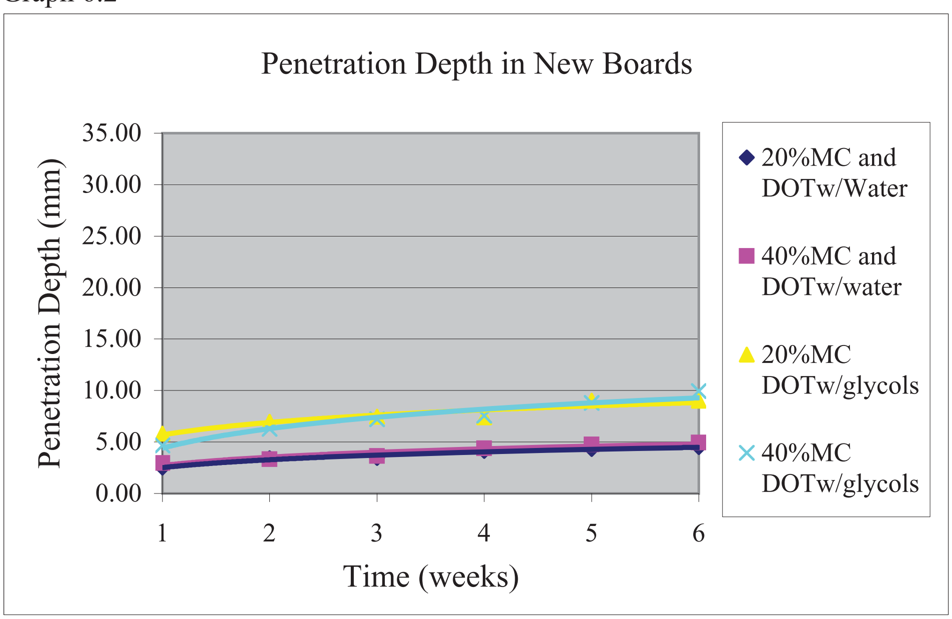
Sample Set	Week	Average Result of Penetration for New Board 5 (mm)	Average Result of Penetration for All Samples (mm)	Difference Between NWB5 and All (mm)
1	1	2.72	2.49	0.23
1	2	4.53	3.40	1.13
1	3	3.96	3.30	0.66
1	4	4.72	3.94	0.77
1	5	4.65	4.28	0.38
1	6	4.84	4.41	0.42
2	1	3.19	2.88	0.31
2	2	3.59	3.24	0.35
2	3	3.74	3.60	0.14
2	4	4.87	4.21	0.66
2	5	4.86	4.70	0.16
2	6	5.27	4.82	0.45
3	1	7.29	6.68	0.62
3	2	7.53	6.94	0.59
3	3	9.26	7.40	1.86
3	4	8.83	7.38	1.45
3	5		9.14	
3	6	9.60	9.28	0.32
4	1	5.40	4.73	0.68
4	2	7.16	6.40	0.76
4	3	8.66	7.37	1.29
4	4	8.30	7.53	0.77
4	5	10.53	8.76	1.77
4	6	10.48	9.96	0.52

Penetration Depth Over Time

Graph 6.1

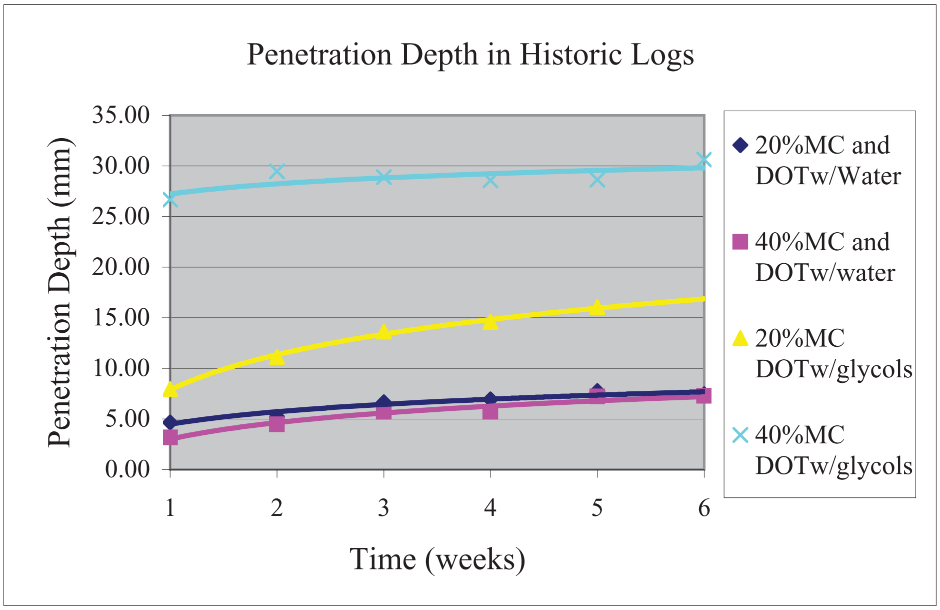


Graph 6.2

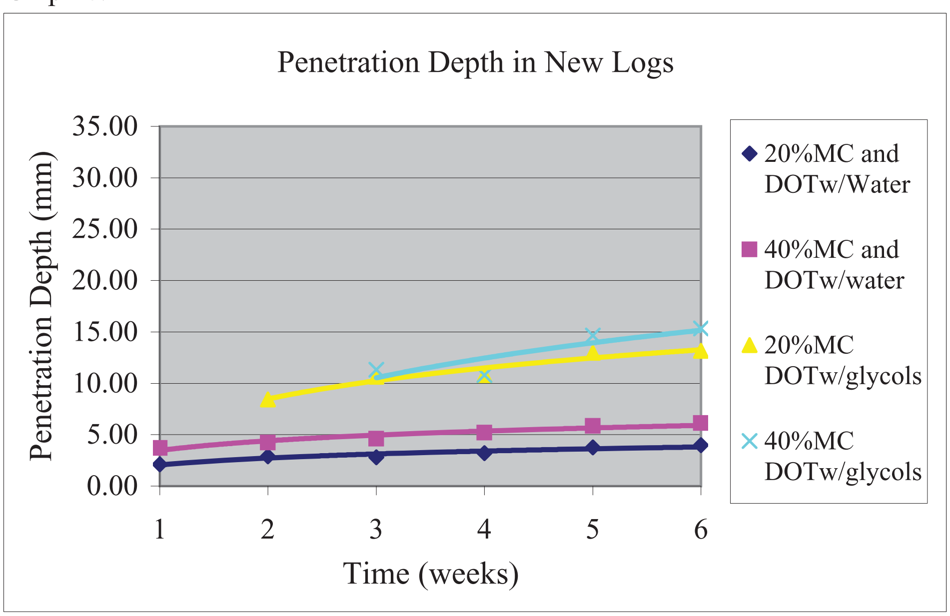


Penetration Depth Over Time

Graph 6.3



Graph 6.4



Conclusion

In the end, the only clear correlation between a tested variable and penetration depth proved to be the vehicle of treatment. DOT in glycols penetrated deeper in all samples, regardless of wood type, age, or initial moisture content. Its performance in the lower moisture content samples is of particular importance to Virginia City, where much of the wood remains dry but still susceptible to attack from wood-boring insects. Two factors likely contribute to the difference in penetration depth between DOT in water and DOT in glycols.

First, it was noted that the samples treated with DOT in water had a white crystalline coating a week after initial treatment. A small sample was removed, dissolved in water, and tested with curcumin-salicylic reagent. It tested positive for DOT. If the DOT is crystallizing on the surface, it is not penetrating into the wood. Secondly, glycols are hydroscopic, and as such hold water in the wood, thereby allowing diffusion of borates to continue after excess water has dried from samples treated with water only.

The aged nature of the historic wood did not negatively impact penetration, as was initially suspected to be the case, and in fact encouraged greater diffusion for the logs tested. For the prevention of decay in the historic wooden buildings in Virginia City, Montana, the use of borates in glycols is highly recommended. Pre-treating replacement wood would likely decrease the frequency of replacement and thorough remedial treatment would decrease the risk of material loss.

Treatment application method by brush was utilized in this experiment as a way to control application to samples of small dimension. As was noted with the logs, the surface tension of the solution could not be overcome by capillary action in some of the larger checks. Therefore, it is recommended that remedial applications be carried out under mild pressure, thereby forcing the solution into the wood. Pressure could be attained by the use of a common garden sprayer, ensuring penetration into larger checks.

Pretreatment could be carried out by dipping or spray. While there was not a large enough sample set to draw hard conclusions, the samples treated by dipping did not yield significantly higher penetration depths than those treated by brushing. Table 6.6 shows the comparison between NWB5 (treated by dipping) and all samples. In all cases, the samples treated by dipping exhibited deeper penetration, but the difference at the conclusion of testing was generally less than 0.5mm. The results invite further research. The only real difference was the totality of coverage, as seen in figure 6.1. Treatment by dipping would ensure every surface receives exposure to the borate solution, but careful spray application could attain the same results. While dipping requires additional equipment, namely a vat large enough to hold the pieces for treatment, the major issue becomes one of waste. The quantity of solution needed to treat by sprayed is much less than required to treat by dipping, and once mixed, borate solutions are not meant to be kept for extended periods of time. This could result in a large quantity of waste solution, and with an already tight

Figure 6.1: NWB5.2, week 6 testing, showing totality of coverage around entire surface as a result of treatment by dipping.

budget, waste should be minimized.

If the Montana Heritage Commission was serious about incorporating borates into the preservation policy, setting up a dip diffusion process might make sense, as wood could be treated in batches. However, since repairs are generally made piece meal, and often in very custom ways, treating a large stock of wood may not be the most practical solution.

Addressing concerns of retreatment, the schedule depends largely on exposure. Borates are considered a highly stable compound, with very little degradation occurring over time. As long as borates are used in an environment where running water is not present, there should be no great hurry for reapplication. As for retreatment where leaching is likely, that is, outdoor situations or ground contact, literature supports the idea that even if leaching occurs, levels of borates are not likely to fall below efficacious levels as long as there is sufficient loading of the chemical initially. Further investigation of the permanence of borates would be an excellent compliment to this research.

Pre-treatment of replacement wood and remedial treatment of historic wood by spray application with borates in glycol emerges as the most efficacious treatment option for Virginia City, Montana. Experimentation has shown that the aged quality of wood does not negatively impact the penetration of borates into the material. The many positive aspects of borate solutions make them an ideal candidate for the treatment of historic structures, and the building stock at Virginia City is no exception.

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Appendices

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1	HWL1	1	E	R	1	3.47
2	HWL1	1	E	R	2	2.92
3	HWL1	1	E	R	3	2.91
4	HWL1	1	E	R	4	7.14
5	HWL1	1	E	R	5	28.12
6	HWL1	1	E	R	6	2.13
7	HWL1	1	E	R	7	3.51
8	HWL1	1	C	T	8	10.56
9	HWB1	1	E	T	1	2.10
10	HWB1	1	E	T	2	2.95
11	HWB1	1	E	T	3	2.94
12	HWB1	1	E	T	4	3.33
13	HWB5	1	E	T	1	2.97
14	HWB5	1	E	T	2	2.53
15	HWB5	1	E	T	3	3.29
16	HWB5	1	E	T	4	2.87
17	HWB9	1	E	R	1	3.46
18	HWB9	1	E	R	2	1.69
19	HWB9	1	E	R	3	2.23
20	HWB9	1	E	R	4	2.96
21	NWL1.1	1	E	R	1	1.99
22	NWL1.1	1	E	R	2	1.15
23	NWL1.1	1	E	R	3	2.06
24	NWL1.1	1	E	R	4	2.24
25	NWL1.1	1	C	T	5	1.85
26	NWL1.1	1	C	T	6	2.31
27	NWL3.1	1	E	R	1	2.07
28	NWL3.1	1	E	R	2	2.65
29	NWL3.1	1	E	R	3	2.17
30	NWL3.1	1	E	R	4	2.18
31	NWL4.1	1	E	R	1	1.81
32	NWL4.1	1	E	R	2	2.53
33	NWL4.1	1	E	R	3	2.16
34	NWL4.1	1	E	R	4	1.80
35	NWL5.1	1	E	R	1	2.18
36	NWL5.1	1	E	R	2	1.34
37	NWL5.1	1	E	R	3	1.96
38	NWL5.1	1	E	R	4	1.53
39	NWL5.1	1	C	T	5	2.67
40	NWL5.1	1	C	T	6	2.67
41	NWB1.1	1	E	T	1	1.92
42	NWB1.1	1	E	T	2	2.33
43	NWB1.1	1	E	T	3	2.29
44	NWB1.1	1	E	T	4	1.95
45	NWB2.1	1	E	R/T	1	1.24
46	NWB2.1	1	E	R/T	2	1.81
47	NWB2.1	1	E	R/T	3	1.82
48	NWB2.1	1	E	R	4	3.12
49	NWB3.1	1	E	R	1	1.72
50	NWB3.1	1	E	R	2	2.10
51	NWB3.1	1	E	R	3	2.10
52	NWB3.1	1	E	R	4	1.73
53	NWB4.1	1	E	T	1	2.76
54	NWB4.1	1	E	T	2	2.34

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
55	NWB4.1	1	E	T	3	2.02
56	NWB4.1	1	E	T	4	1.58
57	NWB5.1	1	E	R/T	1	2.42
58	NWB5.1	1	E	R/T	2	2.92
59	NWB5.1	1	E	R	3	2.92
60	NWB5.1	1	E	R	4	2.92
61	NWB5.1	1	E	T	5	2.56
62	NWB5.1	1	E	R	6	3.02
63	NWB5.1	1	E	R	7	3.01
64	NWB5.1	1	E	R/T	8	3.01
65	NWB5.1	1	E	T	9	2.50
66	NWB5.1	1	E	R/T	10	1.91
67	NWB6.1	1	E	R/T	1	2.21
68	NWB6.1	1	E	T	2	2.68
69	NWB6.1	1	E	T	3	3.20
70	NWB6.1	1	E	T	4	3.49
71	NWB6.2	1	E	R/T	1	2.00
72	NWB6.2	1	E	T	2	1.99
73	NWB6.2	1	E	T	3	2.00
74	NWB6.2	1	E	T	4	2.76
75	NWB6.3	1	E	T	1	2.67
76	NWB6.3	1	E	T	2	2.60
77	NWB6.3	1	E	T	3	2.60
78	NWB6.3	1	E	T	4	2.60
79	NWB7.1	1	E	R	1	2.67
80	NWB7.1	1	E	R	2	2.74
81	NWB7.1	1	E	R	3	3.64
82	NWB7.1	1	E	R	4	4.69
83	HWL2	1	E	R	1	2.48
84	HWL2	1	E	R	2	3.50
85	HWL2	1	C	T	3	3.98
86	HWL2	1	E	R	4	3.82
87	HWL2	1	E	R	5	3.56
88	HWL2	1	E	R	6	3.02
89	HWL2	1	E	R	7	2.62
90	HWL2	1	C	T	8	3.93
91	HWL2	1	E	R	9	2.65
92	HWL2	1	E	R	10	3.00
93	HWL2	1	E	R/T	11	1.94
94	HWL2	1	E	T	12	3.42
95	HWB2	1	E	R	1	3.61
96	HWB2	1	E	R	2	3.61
97	HWB2	1	E	R	3	2.96
98	HWB2	1	E	R	4	3.62
99	HWB6	1	E	R	1	3.45
100	HWB6	1	E	R	2	3.93
101	HWB6	1	E	R	3	3.94
102	HWB6	1	E	R	4	3.05
103	HWB10	1	E	R/T	1	3.05
104	HWB10	1	E	T	2	3.48
105	HWB10	1	E	T	3	2.88
106	HWB10	1	E	T	4	2.89
107	NWL1.2	1	E	R	1	3.77
108	NWL1.2	1	E	R	2	3.78

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
109	NWL1.2	1	E	R	3	3.43
110	NWL1.2	1	E	R	4	3.90
111	NWL1.2	1	C	T	5	2.82
112	NWL1.2	1	C	T	6	3.14
113	NWL3.2	1	E	R	1	5.25
114	NWL3.2	1	E	R	2	3.91
115	NWL3.2	1	E	R	3	3.92
116	NWL3.2	1	E	R	4	3.99
117	NWL4.2	1	E	R	1	4.45
118	NWL4.2	1	E	R	2	3.94
119	NWL4.2	1	E	R	3	4.23
120	NWL4.2	1	E	R	4	2.14
121	NWL4.2	1	C	T	5	4.50
122	NWL4.2	1	C	T	6	3.04
123	NWL5.2	1	E	R	1	3.42
124	NWL5.2	1	E	R	2	3.49
125	NWL5.2	1	E	R	3	4.26
126	NWL5.2	1	E	R	4	2.72
127	NWL5.2	1	C	T	5	3.86
128	NWB1.2	1	E	R/T	1	2.53
129	NWB1.2	1	E	R/T	2	2.89
130	NWB1.2	1	E	R/T	3	3.76
131	NWB1.2	1	E	R	4	2.82
132	NWB2.2	1	E	R	1	3.33
133	NWB2.2	1	E	R	2	3.10
134	NWB2.2	1	E	R	3	3.09
135	NWB2.2	1	E	R	4	4.38
136	NWB3.2	1	E	R	1	3.05
137	NWB3.2	1	E	R	2	3.07
138	NWB3.2	1	E	R	3	2.88
139	NWB3.2	1	E	R	4	2.77
140	NWB4.2	1	E	R/T	1	1.59
141	NWB4.2	1	E	T	2	3.28
142	NWB4.2	1	E	T	3	3.28
143	NWB4.2	1	E	T	4	2.90
144	NWB5.2	1	E	T	1	3.11
145	NWB5.2	1	E	T	2	2.23
146	NWB5.2	1	E	T	3	3.04
147	NWB5.2	1	E	T	4	3.08
148	NWB5.2	1	E	R	5	2.40
149	NWB5.2	1	E	T	6	3.38
150	NWB5.2	1	E	T	7	3.55
151	NWB5.2	1	E	T	8	3.45
152	NWB5.2	1	E	T	9	4.46
153	NWB6.4	1	E	T	1	2.44
154	NWB6.4	1	E	T	2	2.58
155	NWB6.4	1	E	T	3	1.93
156	NWB6.4	1	E	T	4	1.61
157	NWB6.5	1	E	T	1	2.33
158	NWB6.5	1	E	T	2	2.34
159	NWB6.5	1	E	T	3	2.59
160	NWB6.5	1	E	T	4	2.60
161	NWB6.6	1	E	T	1	2.60
162	NWB6.6	1	E	T	2	1.95

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
163	NWB6.6	1	E	T	3	1.30
164	NWB6.6	1	E	T	4	2.26
165	NWB7.2	1	E	R	1	3.61
166	NWB7.2	1	E	R	2	2.99
167	NWB7.2	1	E	R	3	3.60
168	NWB7.2	1	E	R	4	3.94
169	HWL3	1	E	R	1	27.49
170	HWL3	1	E	R	2	22.98
171	HWL3	1	E	R	3	20.73
172	HWL3	1	E	R	4	17.39
173	HWL3	1	E	R	5	7.85
174	HWL3	1	E	R	6	13.64
175	HWL3	1	E	R	7	9.70
176	HWL3	1	E	R	8	28.84
177	HWL3	1	E	R	9	29.84
178	HWL3	1	E	R/T	10	6.06
179	HWB3	1	E	R/T	1	5.10
180	HWB3	1	E	R/T	2	8.67
181	HWB3	1	E	T	3	9.79
182	HWB3	1	E	T	4	8.00
183	HWB7	1	E	R	1	6.33
184	HWB7	1	E	R	2	6.33
185	HWB7	1	E	R	3	5.32
186	HWB7	1	E	R	4	4.51
187	HWB11	1	E	R	1	6.32
188	HWB11	1	E	R	2	6.32
189	HWB11	1	E	R	3	7.33
190	HWB11	1	E	R	4	6.85
191	NWL1.3	1	E	R	1	24.38
192	NWL1.3	1	E	R	2	6.96
193	NWL1.3	1	E	R	3	8.28
194	NWL1.3	1	E	R	4	7.11
195	NWL1.3	1	C	T	5	3.62
196	NWL3.3	1	E	R	1	17.61
197	NWL3.3	1	E	R	2	18.23
198	NWL3.3	1	E	R	3	17.82
199	NWL3.3	1	E	R	4	18.37
200	NWL4.3	1	E	R	1	7.14
201	NWL4.3	1	E	R	2	10.91
202	NWL4.3	1	E	R	3	12.24
203	NWL4.3	1	E	R	4	26.03
204	NWL5.3	1	E	R	1	16.15
205	NWL5.3	1	E	R	2	16.11
206	NWL5.3	1	E	R	3	13.36
207	NWL5.3	1	E	R	4	11.76
208	NWB1.3	1	E	R	1	7.59
209	NWB1.3	1	E	R/T	2	6.42
210	NWB1.3	1	E	R/T	3	12.87
211	NWB1.3	1	E	R/T	4	9.15
212	NWB2.3	1	E	R	1	14.03
213	NWB2.3	1	E	R	2	6.15
214	NWB2.3	1	E	R	3	6.23
215	NWB2.3	1	E	R	4	15.86
216	NWB3.3	1	E	R	1	5.27

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
217	NWB3.3	1	E	R	2	5.27
218	NWB3.3	1	E	R	3	5.27
219	NWB3.3	1	E	R	4	4.91
220	NWB5.3	1	E	R	1	7.93
221	NWB5.3	1	E	R	2	6.63
222	NWB5.3	1	E	R/T	3	7.33
223	NWB5.3	1	E	R	4	7.28
224	NWB6.7	1	E	T	1	3.65
225	NWB6.7	1	E	T	2	4.68
226	NWB6.7	1	E	T	3	3.03
227	NWB6.7	1	E	T	4	6.78
228	NWB6.8	1	E	T	1	7.15
229	NWB6.8	1	E	T	2	6.05
230	NWB6.8	1	E	T	3	4.34
231	NWB6.8	1	E	T	4	3.96
232	NWB6.9	1	E	T	1	4.27
233	NWB6.9	1	E	T	2	5.26
234	NWB6.9	1	E	T	3	4.60
235	NWB6.9	1	E	T	4	4.97
236	NWB7.3	1	E	R	1	6.72
237	NWB7.3	1	E	R	2	6.73
238	NWB7.3	1	E	R	3	7.13
239	NWB7.3	1	E	R	4	6.16
240	HWL4	1	E	R	1	29.76
241	HWL4	1	E	R	2	27.64
242	HWL4	1	E	R	3	24.32
243	HWL4	1	E	R	4	29.06
244	HWL4	1	E	R	5	22.92
245	HWL4	1	E	R	6	25.35
246	HWL4	1	E	R	7	21.84
247	HWL4	1	E	R	8	32.60
248	HWB4	1	E	R/T	1	4.49
249	HWB4	1	E	R/T	2	7.17
250	HWB4	1	E	T	3	5.71
251	HWB4	1	E	T	4	5.17
252	HWB8	1	E	R/T	1	3.72
253	HWB8	1	E	R/T	2	3.62
254	HWB8	1	E	T	3	3.46
255	HWB8	1	E	T	4	12.27
256	HWB12A	1	E	R	1	7.04
257	HWB12A	1	E	R	2	6.28
258	HWB12A	1	E	R	3	5.68
259	HWB12A	1	E	R	4	7.00
260	NWL1.4	1	E	R	1	4.43
261	NWL1.4	1	E	R	2	8.62
262	NWL1.4	1	E	R	3	27.88
263	NWL1.4	1	E	R	4	31.24
264	NWL3.4	1	E	R	1	13.12
265	NWL3.4	1	E	R	2	18.11
266	NWL3.4	1	E	R	3	8.49
267	NWL3.4	1	C	R	4	10.51
268	NWL4.4	1	E	R	1	18.36
269	NWL4.4	1	E	R	2	16.74
270	NWL4.4	1	E	R	3	18.00

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
271	NWL4.4	1	E	R	4	20.96
272	NWL5.4	1	E	R	1	8.54
273	NWL5.4	1	E	R	2	12.54
274	NWL5.4	1	E	R	3	19.59
275	NWL5.4	1	E	R	4	19.62
276	NWL5.4	1	C	T	5	8.01
277	NWL5.4	1	E	R	6	4.43
278	NWL5.4	1	E	R	7	11.47
279	NWL5.4	1	E	R	8	19.37
280	NWL5.4	1	E	R	9	21.86
281	NWB1.4	1	E	R/T	1	6.52
282	NWB1.4	1	E	R/T	2	4.93
283	NWB1.4	1	E	R/T	3	5.05
284	NWB1.4	1	E	R/T	4	3.62
285	NWB2.4	1	E	R	1	4.27
286	NWB2.4	1	E	R	2	3.11
287	NWB2.4	1	E	R	3	6.51
288	NWB2.4	1	E	R	4	6.51
289	NWB3.4	1	E	R	1	4.26
290	NWB3.4	1	E	R	2	4.44
291	NWB3.4	1	E	R	3	4.14
292	NWB3.4	1	E	R	4	3.55
293	NWB4.4	1	E	R/T	1	4.92
294	NWB4.4	1	E	R/T	2	5.13
295	NWB4.4	1	E	R/T	3	5.91
296	NWB4.4	1	E	R/T	4	4.48
297	NWB5.4	1	E	T	1	6.66
298	NWB5.4	1	E	T	2	5.85
299	NWB5.4	1	E	T	3	4.85
300	NWB5.4	1	E	T	4	4.26
301	NWB5.4	1	E	R/T	5	4.28
302	NWB5.4	1	E	T	6	4.57
303	NWB5.4	1	E	T	7	4.26
304	NWB5.4	1	E	T	8	5.65
305	NWB5.4	1	E	T	9	8.25
306	NWB6.10	1	E	T	1	4.48
307	NWB6.10	1	E	T	2	4.81
308	NWB6.10	1	E	T	3	4.30
309	NWB6.10	1	E	T	4	4.99
310	NWB6.11	1	E	T	1	3.74
311	NWB6.11	1	E	T	2	3.77
312	NWB6.11	1	E	T	3	4.30
313	NWB6.11	1	E	T	4	3.97
314	NWB6.12	1	E	T	1	3.32
315	NWB6.12	1	E	T	2	3.30
316	NWB6.12	1	E	T	3	3.47
317	NWB6.12	1	E	T	4	3.95
318	NWB7.4	1	E	R	1	3.86
319	NWB7.4	1	E	R	2	3.88
320	NWB7.4	1	E	R	3	6.50
321	NWB7.4	1	E	R	4	5.17
322	HWL1	2	E	R	1	7.94
323	HWL1	2	E	R	2	3.90
324	HWL1	2	C	R	3	4.10

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
325	HWL1	2	E	R	4	4.14
326	HWL1	2	E	R	5	3.45
327	HWL1	2	E	R	6	3.68
328	HWL1	2	E	R	7	6.57
329	HWL1	2	E	R	8	8.04
330	HWB5	2	E	R	1	3.21
331	HWB5	2	E	R	2	3.46
332	HWB5	2	E	R	3	3.46
333	HWB5	2	E	R	4	2.57
334	HWB1	2	E	T	1	3.61
335	HWB1	2	E	T	2	3.74
336	HWB1	2	E	R/T	3	4.84
337	HWB1	2	E	R/T	4	4.19
338	HWB9	2	E	T	1	3.70
339	HWB9	2	E	T	2	3.70
340	HWB9	2	E	R/T	3	3.41
341	HWB9	2	E	R	4	3.09
342	NWL5.1	2	E	R	1	3.10
343	NWL5.1	2	E	R	2	2.31
344	NWL5.1	2	E	R	3	3.12
345	NWL5.1	2	E	R	4	2.84
346	NWL5.1	2	C	T	5	4.10
347	NWL4.1	2	E	R	1	2.49
348	NWL4.1	2	E	R	2	3.32
349	NWL4.1	2	E	R	3	2.89
350	NWL4.1	2	E	R	4	4.30
351	NWL3.1	2	E	R	1	2.79
352	NWL3.1	2	E	R	2	2.79
353	NWL3.1	2	E	R	3	2.79
354	NWL3.1	2	E	R	4	2.79
355	NWL1.1	2	E	R	1	3.11
356	NWL1.1	2	E	R	2	3.09
357	NWL1.1	2	E	R	3	2.49
358	NWL1.1	2	E	R	4	2.66
359	NWL1.1	2	C	T	5	3.52
360	NWB7.1	2	E	R	1	1.58
361	NWB7.1	2	E	R	2	2.03
362	NWB7.1	2	E	R	3	3.08
363	NWB7.1	2	E	R	4	2.02
364	NWB6.3	2	E	R/T	1	3.27
365	NWB6.3	2	E	T	2	3.74
366	NWB6.3	2	E	T	3	4.09
367	NWB6.3	2	E	T	4	2.99
368	NWB6.2	2	E	R/T	1	2.39
369	NWB6.2	2	E	R/T	2	3.92
370	NWB6.2	2	E	T	3	2.81
371	NWB6.2	2	E	T	4	2.82
372	NWB6.1	2	E	R/T	1	3.01
373	NWB6.1	2	E	T	2	2.75
374	NWB6.1	2	E	T	3	3.58
375	NWB6.1	2	E	T	4	3.91
376	NWB5.1	2	E	R/T	1	3.24
377	NWB5.1	2	E	R/T	2	3.78
378	NWB5.1	2	E	R	3	3.78

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
379	NWB5.1	2	E	R	4	4.00
380	NWB5.1	2	E	T	5	3.99
381	NWB5.1	2	E	R	6	6.55
382	NWB5.1	2	E	R/T	7	4.72
383	NWB5.1	2	E	R/T	8	4.46
384	NWB5.1	2	E	R/T	9	4.45
385	NWB5.1	2	E	R/T	10	6.30
386	NWB4.1	2	E	T	1	3.02
387	NWB4.1	2	E	T	2	3.27
388	NWB4.1	2	E	T	3	4.40
389	NWB4.1	2	E	T	4	3.59
390	NWB3.1	2	E	R	1	2.90
391	NWB3.1	2	E	R	2	2.06
392	NWB3.1	2	E	R	3	2.78
393	NWB3.1	2	E	R	4	2.22
394	NWB2.1	2	E	R	1	2.33
395	NWB2.1	2	E	R	2	3.71
396	NWB2.1	2	E	R	3	5.20
397	NWB2.1	2	E	R	4	2.72
398	NWB1.1	2	E	R/T	1	2.29
399	NWB1.1	2	E	R/T	2	3.17
400	NWB1.1	2	E	R	3	3.17
401	NWB1.1	2	E	R	4	2.75
402	HWB2	2	E	R	1	3.89
403	HWB2	2	E	R	2	4.39
404	HWB2	2	E	R	3	3.33
405	HWB2	2	E	R	4	3.33
406	HWB6	2	E	R	1	3.84
407	HWB6	2	E	R	2	4.53
408	HWB6	2	E	R	3	3.77
409	HWB6	2	E	R	4	3.31
410	HWB10	2	E	R	1	4.85
411	HWB10	2	E	R	2	3.76
412	HWB10	2	E	R/T	3	3.88
413	HWB10	2	E	T	4	4.69
414	HWL2	2	E	R	1	6.01
415	HWL2	2	C	T	2	6.30
416	HWL2	2	E	R	3	5.32
417	HWL2	2	E	R	4	4.66
418	HWL2	2	E	R	5	5.13
419	HWL2	2	E	R	6	3.79
420	HWL2	2	E	R	7	5.15
421	HWL2	2	E	R	8	3.92
422	HWL2	2	C	T	9	4.16
423	HWL2	2	E	R	10	4.16
424	HWL2	2	E	R	11	4.39
425	HWL2	2	E	R	12	2.54
426	HWL2	2	E	R/T	13	2.38
427	NWL1.2	2	E	R	1	4.54
428	NWL1.2	2	E	R	2	3.67
429	NWL1.2	2	E	R	3	3.69
430	NWL1.2	2	E	R	4	5.57
431	NWL3.2	2	E	R	1	4.69
432	NWL3.2	2	E	R	2	4.10

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
433	NWL3.2	2	E	R	3	4.26
434	NWL3.2	2	E	R	4	3.01
435	NWL4.2	2	E	R	1	7.59
436	NWL4.2	2	E	R	2	5.28
437	NWL4.2	2	E	R	3	4.60
438	NWL4.2	2	C	T	5	5.17
439	NWL4.2	2	E	R	4	3.10
440	NWL5.2	2	E	R	1	3.03
441	NWL5.2	2	E	R	2	4.88
442	NWL5.2	2	E	R	3	4.61
443	NWL5.2	2	E	R	4	3.62
444	NWL5.2	2	E	T	5	7.16
445	NWL5.2	2	E	T	6	4.12
446	NWB1.2	2	E	R/T	1	3.39
447	NWB1.2	2	E	R/T	2	2.68
448	NWB1.2	2	E	R/T	3	3.50
449	NWB1.2	2	E	R/T	4	3.15
450	NWB2.2	2	E	R	1	3.63
451	NWB2.2	2	E	R	2	3.51
452	NWB2.2	2	E	R	3	2.70
453	NWB2.2	2	E	R	4	2.18
454	NWB3.2	2	E	R	1	2.18
455	NWB3.2	2	E	R	2	2.23
456	NWB3.2	2	E	R	3	3.06
457	NWB3.2	2	E	R	4	3.10
458	NWB4.2	2	E	R/T	1	2.80
459	NWB4.2	2	E	R/T	2	3.24
460	NWB4.2	2	E	T	3	3.10
461	NWB4.2	2	E	T	4	2.89
462	NWB5.2	2	E	T	1	3.45
463	NWB5.2	2	E	T	2	3.97
464	NWB5.2	2	E	T	3	3.85
465	NWB5.2	2	E	T	4	4.40
466	NWB5.2	2	E	R	5	3.99
467	NWB5.2	2	E	T	6	3.17
468	NWB5.2	2	E	T	7	2.82
469	NWB5.2	2	E	T	8	2.96
470	NWB5.2	2	E	T	9	3.02
471	NWB5.2	2	E	R/T	10	4.29
472	NWB6.4	2	E	T	1	2.94
473	NWB6.4	2	E	T	2	3.04
474	NWB6.4	2	E	T	3	3.27
475	NWB6.4	2	E	T	4	4.30
476	NWB6.5	2	E	R/T	1	3.71
477	NWB6.5	2	E	R/T	2	3.22
478	NWB6.5	2	E	T	3	4.04
479	NWB6.5	2	E	T	4	3.68
480	NWB6.6	2	E	R/T	1	3.60
481	NWB6.6	2	E	T	2	4.30
482	NWB6.6	2	E	T	3	2.65
483	NWB6.6	2	E	T	4	2.67
484	NWB7.2	2	E	R	1	2.66
485	NWB7.2	2	E	R	2	3.16
486	NWB7.2	2	E	R	3	2.78

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
487	NWB7.2	2	E	R	4	2.78
488	HWL3	2	E	R	1	13.12
489	HWL3	2	C	T	2	3.00
490	HWL3	2	E	R	3	7.79
491	HWL3	2	E	R	4	9.71
492	HWL3	2	C	T	5	4.47
493	HWL3	2	E	R	6	9.11
494	HWL3	2	E	R	7	9.64
495	HWL3	2	C	T	8	5.28
496	HWL3	2	E	R	9	10.70
497	HWL3	2	E	R	10	12.15
498	HWL3	2	E	R	11	5.01
499	HWL3	2	E	R	12	5.25
500	HWB3	2	E	R/T	1	6.83
501	HWB3	2	E	R/T	2	5.20
502	HWB3	2	E	R/T	3	4.38
503	HWB3	2	E	T	4	10.25
504	HWB7	2	E	R	1	18.85
505	HWB7	2	E	R/T	2	18.78
506	HWB7	2	E	R/T	3	15.46
507	HWB7	2	E	R/T	4	15.11
508	HWB11	2	E	R	1	9.08
509	HWB11	2	E	R	2	9.10
510	HWB11	2	E	R	3	8.64
511	HWB11	2	E	R	4	8.16
512	NWL5.3	2	E	R	1	7.97
513	NWL5.3	2	E	R	2	6.75
514	NWL5.3	2	E	R	3	12.70
515	NWL5.3	2	E	R	4	8.73
516	NWL4.3	2	E	R	3	8.78
517	NWL4.3	2	E	R	2	9.05
518	NWL4.3	2	E	R	1	11.55
519	NWL3.3	2	E	R	1	9.04
520	NWL3.3	2	E	R	2	8.67
521	NWL3.3	2	C	T	3	5.80
522	NWL3.3	2	E	R	4	8.94
523	NWL1.3	2	E	R	1	12.32
524	NWL1.3	2	E	R	2	8.50
525	NWL1.3	2	E	R	3	8.28
526	NWL1.3	2	C	T	4	4.52
527	NWB1.3	2	E	R	1	7.25
528	NWB1.3	2	E	R/T	2	7.04
529	NWB1.3	2	E	R/T	3	6.13
530	NWB1.3	2	E	R/T	4	8.44
531	NWB2.3	2	E	R	1	10.25
532	NWB2.3	2	E	R	2	8.72
533	NWB2.3	2	E	R	3	9.56
534	NWB2.3	2	E	R	4	11.07
535	NWB3.3	2	E	R	1	6.69
537	NWB3.3	2	E	R	2	6.58
538	NWB3.3	2	E	R	3	5.90
539	NWB3.3	2	E	R	4	7.20
540	NWB5.3	2	E	R/T	1	9.54
541	NWB5.3	2	E	R/T	2	6.07

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
542	NWB5.3	2	E	R	3	7.37
543	NWB5.3	2	E	R	4	8.67
544	NWB5.3	2	E	T	5	4.68
545	NWB5.3	2	E	R	6	7.89
546	NWB5.3	2	E	R	7	7.61
547	NWB5.3	2	E	R	8	8.42
548	NWB6.7	2	E	T	1	4.89
549	NWB6.7	2	E	T	2	5.46
550	NWB6.7	2	E	T	3	5.70
551	NWB6.7	2	E	T	4	6.08
552	NWB6.8	2	E	T	1	5.31
553	NWB6.8	2	E	T	2	6.52
554	NWB6.8	2	E	T	3	4.15
555	NWB6.8	2	E	T	4	7.29
556	NWB6.9	2	E	T	1	6.11
557	NWB6.9	2	E	T	2	4.93
558	NWB6.9	2	E	T	3	5.72
559	NWB6.9	2	E	T	4	4.86
560	HWL4	2	E	R	1	31.71
561	HWL4	2	E	R	2	30.60
562	HWL4	2	E	R	3	28.08
563	HWL4	2	E	R	4	30.27
564	HWL4	2	E	R	5	28.98
565	HWL4	2	E	R	6	28.19
566	HWL4	2	E	R	7	28.41
567	HWL4	2	E	R	8	45.62
568	HWB4	2	E	R/T	1	6.07
569	HWB4	2	E	R/T	2	5.94
570	HWB4	2	E	R/T	3	6.37
571	HWB4	2	E	T	4	7.49
572	HWB8	2	E	R/T	1	7.76
573	HWB8	2	E	R/T	2	6.05
574	HWB8	2	E	R/T	3	5.40
575	HWB8	2	E	R/T	4	8.44
576	HWB12	2	E	R	1	25.23
577	NWL5.4	2	E	R	1	9.52
578	NWL5.4	2	E	R	2	13.48
579	NWL5.4	2	E	R	3	16.95
581	NWL4.4	2	E	R	1	21.55
582	NWL4.4	2	E	R	2	21.55
583	NWL4.4	2	E	R	3	22.93
584	NWL4.4	2	E	R	4	17.47
585	NWL3.4	2	E	R	1	6.47
586	NWL3.4	2	E	R	2	10.19
587	NWL3.4	2	E	R	3	11.60
588	NWL3.4	2	E	R	4	7.96
589	NWL1.4	2	E	R	1	6.59
590	NWL1.4	2	E	R	2	6.36
591	NWL1.4	2	E	R	3	9.21
592	NWB1.4	2	E	R/T	1	7.44
593	NWB1.4	2	E	R/T	2	8.16
594	NWB1.4	2	E	R/T	3	5.94
595	NWB1.4	2	E	R/T	4	5.26
596	NWB2.4	2	E	R	1	7.21

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
597	NWB2.4	2	E	R	2	7.57
598	NWB2.4	2	E	R	3	7.72
599	NWB2.4	2	E	R	4	6.66
600	NWB3.4	2	E	R	1	7.05
601	NWB3.4	2	E	R	2	5.21
602	NWB3.4	2	E	R	3	5.67
603	NWB3.4	2	E	R	4	6.35
604	NWB4.4	2	E	R/T	1	6.35
605	NWB4.4	2	E	R/T	2	6.64
606	NWB4.4	2	E	R/T	3	6.29
607	NWB4.4	2	E	R/T	4	6.55
608	NWB5.4	2	E	T	1	6.78
609	NWB5.4	2	E	T	2	6.69
610	NWB5.4	2	E	T	3	6.70
611	NWB5.4	2	E	R	4	9.91
612	NWB5.4	2	E	T	5	7.54
613	NWB5.4	2	E	T	6	6.45
614	NWB5.4	2	E	T	7	6.02
615	NWB6.10	2	E	T	1	5.98
616	NWB6.10	2	E	T	2	5.35
617	NWB6.10	2	E	T	3	6.05
618	NWB6.10	2	E	T	4	4.61
619	NWB6.11	2	E	T	1	6.14
620	NWB6.11	2	E	T	2	6.88
621	NWB6.11	2	E	T	3	6.34
622	NWB6.11	2	E	T	4	4.91
623	NWB6.12	2	E	T	1	4.50
624	NWB6.12	2	E	T	2	5.46
625	NWB6.12	2	E	T	3	5.46
626	NWB6.12	2	E	T	4	5.46
627	NWB7.4	2	E	R	1	5.89
628	NWB7.4	2	E	R	2	7.55
629	HWL1	3	E	R	1	10.67
630	HWL1	3	E	R	2	11.46
631	HWL1	3	E	R	3	4.05
632	HWL1	3	C	T	4	3.08
633	HWL1	3	E	R	5	3.85
634	HWL1	3	E	R	6	3.52
635	HWL1	3	C	T	7	4.99
636	HWL1	3	E	R	8	8.40
637	HWL1	3	E	R	9	9.46
638	HWL1	3	E	R/T	10	9.62
639	HWL1	3	E	R/T	11	3.95
640	HWB1	3	E	R/T	1	3.77
641	HWB1	3	E	R/T	2	3.36
642	HWB1	3	E	R/T	3	4.00
644	HWB1	3	E	R/T	4	3.73
645	HWB9	3	E	R	1	3.81
646	HWB9	3	E	R/T	2	2.40
647	HWB9	3	E	R/T	3	2.92
648	HWB9	3	E	R/T	4	3.83
649	HWB5	3	E	R	1	2.52
650	HWB5	3	E	R	2	3.21
651	HWB5	3	E	R	3	2.25

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
652	HWB5	3	E	R	4	2.91
653	NWL5.1	3	E	R	1	2.54
654	NWL5.1	3	E	R	2	2.56
655	NWL5.1	3	E	R	3	2.62
656	NWL5.1	3	E	R	4	3.05
657	NWL4.1	3	E	R	1	2.88
659	NWL4.1	3	E	R	2	2.79
660	NWL4.1	3	E	R	3	3.07
661	NWL4.1	3	E	R	4	3.07
662	NWL3.1	3	E	R	1	3.07
663	NWL3.1	3	E	R	2	3.07
664	NWL3.1	3	E	R	3	3.07
665	NWL3.1	3	E	R	4	3.84
666	NWL1.1	3	E	R	1	2.25
667	NWL1.1	3	E	R	2	2.47
668	NWL1.1	3	E	R	3	2.71
669	NWL1.1	3	E	R	4	3.02
670	NWL1.1	3	C	T	5	2.88
671	NWB1.1	3	E	R/T	1	3.21
672	NWB1.1	3	E	R	2	3.37
673	NWB1.1	3	E	R	3	3.38
674	NWB1.1	3	E	R	4	3.90
675	NWB2.1	3	E	R	1	3.09
676	NWB2.1	3	E	R	2	3.13
677	NWB2.1	3	E	R	3	3.28
678	NWB2.1	3	E	R	4	2.92
679	NWB3.1	3	E	R	1	3.12
680	NWB3.1	3	E	R	2	3.43
681	NWB3.1	3	E	R	3	3.27
682	NWB3.1	3	E	R	4	3.10
683	NWB5.1	3	E	R	1	3.59
684	NWB5.1	3	E	R	2	4.33
685	NWB5.1	3	E	R/T	3	3.74
686	NWB5.1	3	E	R/T	4	4.05
687	NWB5.1	3	E	R/T	5	4.20
688	NWB5.1	3	E	R/T	6	4.30
689	NWB5.1	3	E	R	7	3.92
690	NWB5.1	3	E	R	8	3.81
691	NWB5.1	3	E	R	9	3.71
692	NWB6.1	3	E	R/T	1	2.85
693	NWB6.1	3	E	R/T	2	2.88
694	NWB6.1	3	E	T	3	3.06
695	NWB6.1	3	E	T	4	3.50
696	NWB6.2	3	E	T	1	2.76
697	NWB6.2	3	E	T	2	2.88
698	NWB6.2	3	E	T	3	2.88
699	NWB6.2	3	E	T	4	2.21
700	NWB6.3	3	E	R/T	1	3.34
701	NWB6.3	3	E	T	2	4.03
702	NWB6.3	3	E	T	3	3.57
703	NWB6.3	3	E	T	4	2.64
704	NWB7.1	3	E	R	1	2.48
706	NWB7.1	3	E	R	2	2.88
707	NWB7.1	3	E	R	3	2.56

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
708	NWB7.1	3	E	R	4	3.07
709	HWL2	3	E	R	1	5.30
710	HWL2	3	E	R	2	8.02
711	HWL2	3	C	T	3	6.72
712	HWL2	3	E	R	4	7.04
713	HWL2	3	E	R	5	4.71
714	HWL2	3	C	T	6	6.40
715	HWL2	3	E	R	7	4.57
716	HWL2	3	E	R	8	5.60
717	HWL2	3	E	R	9	5.86
718	HWL2	3	E	R	10	4.80
719	HWL2	3	E	R	11	3.79
720	HWB10	3	E	R	1	4.98
721	HWB10	3	E	R/T	2	3.70
722	HWB10	3	E	R/T	3	4.47
723	HWB10	3	E	R/T	4	6.05
724	HWB6	3	E	R	1	4.62
725	HWB6	3	E	R	2	5.08
726	HWB6	3	E	R	3	5.31
727	HWB6	3	E	R	4	5.08
728	HWB2	3	E	R	1	4.32
729	HWB2	3	E	R	2	4.35
730	HWB2	3	E	R	3	4.65
731	HWB2	3	E	R	4	4.77
732	NWL5.2	3	E	R	1	4.33
733	NWL5.2	3	E	R	2	4.08
734	NWL5.2	3	E	R	3	4.88
735	NWL5.2	3	E	R	4	3.83
736	NWL5.2	3	C	T	5	4.01
737	NWL4.2	3	E	R	1	5.39
738	NWL4.2	3	E	R	2	5.29
739	NWL4.2	3	E	R	3	4.49
740	NWL4.2	3	E	R	4	3.81
741	NWL4.2	3	C	T	5	5.18
742	NWL3.2	3	E	R	1	5.22
743	NWL3.2	3	E	R	2	4.13
744	NWL3.2	3	E	R	3	4.09
745	NWL3.2	3	E	R	4	4.10
746	NWL1.2	3	E	R	1	5.39
747	NWL1.2	3	E	R	2	3.95
748	NWL1.2	3	E	R	3	5.70
749	NWL1.2	3	E	R	4	5.36
750	NWB7.2	3	E	R	1	3.88
751	NWB7.2	3	E	R	2	3.55
752	NWB7.2	3	E	R	3	3.63
753	NWB7.2	3	E	R	4	3.21
754	NWB6.6	3	E	R/T	1	4.36
755	NWB6.6	3	E	T	2	3.52
756	NWB6.6	3	E	T	3	3.75
757	NWB6.6	3	E	T	4	3.66
758	NWB6.5	3	E	R/T	1	4.00
759	NWB6.5	3	E	T	2	3.25
760	NWB6.5	3	E	T	3	3.67
761	NWB6.5	3	E	T	4	3.99

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
762	NWB6.4	3	E	R/T	1	3.31
763	NWB6.4	3	E	T	2	3.16
764	NWB6.4	3	E	T	3	3.42
765	NWB6.4	3	E	T	4	3.87
766	NWB5.2	3	E	T	1	3.79
767	NWB5.2	3	E	T	2	3.99
768	NWB5.2	3	E	T	3	3.92
769	NWB5.2	3	E	T	4	3.83
770	NWB5.2	3	E	T	5	3.83
771	NWB5.2	3	E	T	6	4.10
772	NWB5.2	3	E	T	7	3.50
773	NWB5.2	3	E	T	8	3.10
774	NWB5.2	3	E	T	9	3.83
775	NWB5.2	3	E	T	10	3.50
776	NWB4.2	3	E	R/T	1	3.42
777	NWB4.2	3	E	R/T	2	3.99
778	NWB4.2	3	E	R/T	3	4.57
779	NWB4.2	3	E	R/T	4	4.23
780	NWB3.2	3	E	R	1	3.16
782	NWB3.2	3	E	R	2	3.67
783	NWB3.2	3	E	R	3	4.08
784	NWB3.2	3	E	R	4	3.22
785	NWB2.2	3	E	R	1	2.63
786	NWB2.2	3	E	R	2	2.64
787	NWB2.2	3	E	R	3	2.63
788	NWB2.2	3	E	R	4	3.06
789	NWB2.1	3	E	R/T	1	2.63
791	NWB2.1	3	E	R/T	2	2.90
792	NWB2.1	3	E	R/T	3	3.54
793	NWB2.1	3	E	R	4	3.83
794	HWL3	3	E	R	1	13.61
795	HWL3	3	E	R	2	13.49
796	HWL3	3	E	R	3	11.44
797	HWL3	3	C	T	4	4.39
798	HWL3	3	E	R	5	10.52
799	HWL3	3	E	R	6	11.62
800	HWL3	3	E	R	7	13.43
801	HWL3	3	E	R	8	16.24
802	HWL3	3	E	R	9	8.61
803	HWL3	3	E	R	10	8.17
804	HWB3	3	E	R/T	1	6.69
805	HWB3	3	E	R/T	2	6.60
806	HWB3	3	E	T	3	6.60
807	HWB3	3	E	T	4	13.26
808	HWB7	3	E	R/T	1	7.06
809	HWB7	3	E	R/T	2	5.52
810	HWB7	3	E	T	3	10.83
811	HWB7	3	E	T	4	14.80
812	HWB11	3	E	R	1	11.59
814	HWB11	3	E	R	2	10.47
815	HWB11	3	E	R	3	9.71
816	HWB11	3	E	R	4	9.71
817	NWL5.3	3	E	R	1	12.24
818	NWL5.3	3	E	R	2	9.53

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
819	NWL5.3	3	E	R	3	11.45
820	NWL5.3	3	E	R	4	11.47
821	NWL3.3	3	E	R	1	14.24
822	NWL3.3	3	E	R	2	12.68
823	NWL3.3	3	E	R	3	10.32
824	NWL3.3	3	E	R	4	7.71
825	NWL1.3	3	E	R	1	10.54
826	NWL1.3	3	E	R	2	9.49
827	NWL1.3	3	E	R	3	9.50
828	NWL1.3	3	E	R	4	9.03
829	NWB1.3	3	E	R/T	1	6.47
830	NWB1.3	3	E	R/T	2	6.23
831	NWB1.3	3	E	R/T	3	6.82
832	NWB1.3	3	E	R/T	4	8.17
833	NWB2.3	3	E	R	1	9.91
834	NWB2.3	3	E	R	2	9.45
835	NWB2.3	3	E	R	3	8.11
836	NWB2.3	3	E	R	4	7.85
837	NWB3.3	3	E	R	1	6.83
839	NWB3.3	3	E	R	2	7.07
840	NWB3.3	3	E	R	3	7.66
841	NWB3.3	3	E	R	4	6.42
842	NWB5.3	3	E	R	1	8.55
843	NWB5.3	3	E	R	2	7.90
844	NWB5.3	3	E	R/T	3	8.13
845	NWB5.3	3	E	R/T	4	10.44
846	NWB5.3	3	E	R	5	10.21
847	NWB5.3	3	E	R	6	10.34
848	NWB6.7	3	E	T	1	5.56
849	NWB6.7	3	E	T	2	5.89
850	NWB6.7	3	E	T	3	6.30
851	NWB6.7	3	E	T	4	6.30
852	NWB6.8	3	E	T	1	5.48
853	NWB6.8	3	E	T	2	5.65
854	NWB6.8	3	E	T	3	5.95
855	NWB6.8	3	E	T	4	5.73
856	NWB6.9	3	E	T	1	7.00
857	NWB6.9	3	E	T	2	7.00
858	NWB6.9	3	E	T	3	6.50
859	NWB6.9	3	E	T	4	8.01
860	HWL4	3	E	R	1	31.91
861	HWL4	3	E	R	2	28.76
862	HWL4	3	E	R	3	26.86
863	HWL4	3	E	R	4	26.87
864	HWL4	3	E	R	5	27.32
865	HWL4	3	E	R	6	27.33
866	HWL4	3	E	R	7	33.11
868	HWB4	3	E	R	1	7.46
869	HWB4	3	E	R	2	6.70
870	HWB4	3	E	R/T	3	7.60
871	HWB4	3	E	T	4	7.70
872	HWB8	3	E	R	1	8.03
874	HWB8	3	E	R	2	6.25
875	HWB8	3	E	R/T	3	6.40

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
876	HWB8	3	E	T	4	8.51
877	HWB12	3	E	R	1	7.08
878	HWB12	3	E	R	2	6.64
879	HWB12	3	E	R	3	6.18
880	NWL5.4	3	E	R	1	8.00
881	NWL5.4	3	E	R	2	11.02
882	NWL5.4	3	E	R	3	9.47
884	NWL4.4	3	E	R	1	20.22
885	NWL4.4	3	E	R	2	19.71
886	NWL4.4	3	E	R	3	15.87
887	NWL3.4	3	E	R	1	8.01
888	NWL3.4	3	E	R	2	8.93
889	NWL3.4	3	E	R	3	12.05
890	NWL1.4	3	E	R	1	7.31
891	NWL1.4	3	E	R	2	8.49
892	NWL1.4	3	E	R	3	7.70
894	NWB6.12	3	E	T	1	6.47
895	NWB6.12	3	E	T	2	6.33
896	NWB6.12	3	E	T	3	6.69
897	NWB6.12	3	E	T	4	6.62
898	NWB6.10	3	E	T	1	7.11
899	NWB6.10	3	E	T	2	6.89
900	NWB6.10	3	E	T	3	7.02
901	NWB6.10	3	E	T	4	7.82
902	NWB6.11	3	E	T	1	6.83
903	NWB6.11	3	E	T	2	6.83
904	NWB6.11	3	E	T	3	6.43
905	NWB6.11	3	E	T	4	5.64
906	NWB5.4	3	E	T	1	7.39
907	NWB5.4	3	E	T	2	7.94
908	NWB5.4	3	E	T	3	7.41
909	NWB5.4	3	E	R/T	4	10.25
910	NWB5.4	3	E	T	5	7.64
911	NWB5.4	3	E	T	6	8.32
912	NWB5.4	3	E	R	7	11.65
913	NWB4.4	3	E	R/T	1	7.65
914	NWB4.4	3	E	R/T	2	6.97
915	NWB4.4	3	E	R/T	3	7.64
916	NWB4.4	3	E	R/T	4	8.23
917	NWB3.4	3	E	R	1	6.32
918	NWB3.4	3	E	R	2	6.91
919	NWB3.4	3	E	R	3	7.50
920	NWB3.4	3	E	R	4	7.51
921	NWB2.4	3	E	R	1	6.72
922	NWB2.4	3	E	R	2	6.28
923	NWB2.4	3	E	R	3	7.21
924	NWB2.4	3	E	R	4	6.97
925	NWB1.4	3	E	R/T	1	8.22
926	NWB1.4	3	E	R/T	2	8.57
927	NWB1.4	3	E	R/T	3	6.71
928	NWB1.4	3	E	R/T	4	7.15
929	NWB7.1	4	E	R	1	2.97
930	NWB7.1	4	E	R	2	3.22
931	NWB7.1	4	E	R	3	3.57

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
932	NWB7.1	4	E	R	4	3.10
933	NWB6.3	4	E	R/T	1	3.35
934	NWB6.3	4	E	T	2	3.41
935	NWB6.3	4	E	T	3	3.41
936	NWB6.3	4	E	T	4	4.11
937	NWB6.2	4	E	R/T	1	4.10
939	NWB6.2	4	E	R/T	2	3.24
940	NWB6.2	4	E	T	3	3.49
941	NWB6.2	4	E	T	4	3.62
942	NWB6.1	4	E	R/T	1	3.13
943	NWB6.1	4	E	R/T	2	3.62
944	NWB6.1	4	E	T	3	3.75
945	NWB6.1	4	E	T	4	4.31
946	NWB5.1	4	E	R	1	4.32
947	NWB5.1	4	E	R	2	5.27
948	NWB5.1	4	E	R	3	4.96
949	NWB5.1	4	E	R	4	4.48
950	NWB5.1	4	E	R/T	5	4.22
951	NWB5.1	4	E	R/T	6	4.60
952	NWB5.1	4	E	R	7	4.73
953	NWB5.1	4	E	R	8	5.11
954	NWB5.1	4	E	R	9	4.77
956	NWB4.1	4	E	T	1	4.18
957	NWB4.1	4	E	T	2	4.36
958	NWB4.1	4	E	T	3	4.37
959	NWB4.1	4	E	T	4	4.37
960	NWB3.1	4	E	R	1	3.75
961	NWB3.1	4	E	R	2	3.73
962	NWB3.1	4	E	R	3	3.74
963	NWB3.1	4	E	R	4	3.74
964	NWB2.1	4	E	R	1	3.43
965	NWB2.1	4	E	R	2	3.81
966	NWB2.1	4	E	R	3	3.54
967	NWB2.1	4	E	R	4	3.84
968	NWB1.1	4	E	R/T	1	3.84
969	NWB1.1	4	E	R/T	2	3.84
970	NWB1.1	4	E	R/T	3	4.12
971	NWB1.1	4	E	R	4	4.21
972	NWL1.1	4	E	R	1	3.54
973	NWL1.1	4	E	R	2	2.80
974	NWL1.1	4	E	R	3	3.36
975	NWL1.1	4	E	R	4	3.60
976	NWL1.1	4	C	T	5	3.34
977	NWL3.1	4	E	R	1	3.35
978	NWL3.1	4	E	R	2	3.07
979	NWL3.1	4	E	R	3	3.08
980	NWL3.1	4	E	R	4	2.75
981	NWL4.1	4	E	R	1	3.26
982	NWL4.1	4	E	R	2	3.47
983	NWL4.1	4	E	R	3	3.38
984	NWL4.1	4	E	R	4	3.38
985	NWL5.1	4	E	R	1	2.52
986	NWL5.1	4	E	R	2	3.10
987	NWL5.1	4	E	R	3	3.10

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
988	NWL5.1	4	E	R	4	2.66
989	HWB1	4	E	T	1	3.60
990	HWB1	4	E	T	2	3.26
991	HWB1	4	E	R/T	3	3.31
992	HWB1	4	E	R/T	4	3.40
993	HWB5	4	E	R	1	3.99
995	HWB5	4	E	R	2	4.06
996	HWB5	4	E	R	3	4.00
997	HWB5	4	E	R	4	3.83
998	HWB9	4	E	R	1	3.32
999	HWB9	4	E	R	2	3.23
1000	HWB9	4	E	R/T	3	3.59
1001	HWB9	4	E	R/T	4	3.84
1002	HWL1	4	E	R	1	10.43
1003	HWL1	4	E	R	2	10.57
1004	HWL1	4	E	R	3	4.55
1005	HWL1	4	E	R	4	4.90
1006	HWL1	4	E	R	5	4.27
1007	HWL1	4	E	R	6	3.92
1008	HWL1	4	E	R	7	8.78
1009	HWL1	4	E	R	8	8.00
1010	NWB7.2	4	E	R	1	3.98
1011	NWB7.2	4	E	R	2	3.99
1012	NWB7.2	4	E	R	3	3.94
1013	NWB7.2	4	E	R	4	4.48
1014	NWB6.6	4	E	R/T	1	3.85
1015	NWB6.6	4	E	T	2	3.85
1016	NWB6.6	4	E	T	3	3.84
1017	NWB6.6	4	E	T	4	3.59
1018	NWB6.5	4	E	R/T	1	3.78
1019	NWB6.5	4	E	T	2	3.51
1020	NWB6.5	4	E	T	3	4.44
1021	NWB6.5	4	E	T	4	4.44
1022	NWB6.4	4	E	T	1	4.27
1023	NWB6.4	4	E	T	2	4.01
1024	NWB6.4	4	E	T	3	4.01
1025	NWB6.4	4	E	T	4	3.70
1026	NWB5.2	4	E	T	1	5.04
1027	NWB5.2	4	E	T	2	5.03
1028	NWB5.2	4	E	T	3	4.69
1029	NWB5.2	4	E	T	4	4.69
1030	NWB5.2	4	E	R/T	5	4.70
1031	NWB5.2	4	E	T	6	5.51
1032	NWB5.2	4	E	T	7	5.51
1033	NWB5.2	4	E	T	8	5.17
1034	NWB5.2	4	E	T	9	4.43
1035	NWB5.2	4	E	T	10	3.89
1036	NWB3.2	4	E	R	1	4.17
1037	NWB3.2	4	E	R	2	4.19
1038	NWB3.2	4	E	R	3	4.59
1039	NWB3.2	4	E	R	4	4.60
1040	NWB4.2	4	E	R	1	3.83
1042	NWB4.2	4	E	R	2	4.01
1043	NWB4.2	4	E	R	3	4.06

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1044	NWB4.2	4	E	R	4	4.64
1045	NWB2.2	4	E	R	1	2.87
1046	NWB2.2	4	E	R	2	3.61
1047	NWB2.2	4	E	R	3	4.02
1048	NWB2.2	4	E	R	4	3.74
1049	NWB1.2	4	E	R/T	1	3.74
1050	NWB1.2	4	E	R/T	2	4.46
1051	NWB1.2	4	E	R/T	3	3.71
1052	NWB1.2	4	E	R	4	4.10
1053	NWL1.2	4	E	R	1	4.73
1054	NWL1.2	4	E	R	2	4.34
1055	NWL1.2	4	E	R	3	4.67
1056	NWL1.2	4	E	R	4	6.00
1057	NWL1.2	4	C	T	5	4.65
1058	NWL3.2	4	E	R	1	5.67
1059	NWL3.2	4	C	T	5	5.92
1060	NWL3.2	4	E	R	2	4.49
1061	NWL3.2	4	E	R	3	4.97
1062	NWL3.2	4	E	R	4	4.84
1063	NWL4.2	4	E	R	1	6.39
1064	NWL4.2	4	E	R	2	6.31
1065	NWL4.2	4	E	R	3	5.24
1066	NWL4.2	4	E	R	4	4.87
1067	NWL4.2	4	C	T	5	7.03
1068	NWL5.2	4	E	R	1	4.80
1069	NWL5.2	4	E	R	2	5.19
1070	NWL5.2	4	E	R	3	3.64
1071	NWL5.2	4	E	R	4	3.96
1072	NWL5.2	4	C	T	5	5.81
1073	HWL2	4	E	R	1	6.52
1074	HWL2	4	E	R	2	7.47
1075	HWL2	4	E	R	3	8.63
1076	HWL2	4	E	R	4	6.15
1077	HWL2	4	E	R	5	5.59
1078	HWL2	4	E	R	6	5.54
1079	HWL2	4	E	R	7	4.20
1080	HWL2	4	E	R	8	6.28
1081	HWL2	4	E	R	9	5.37
1082	HWL2	4	E	R	10	4.06
1083	HWB10	4	E	R	1	4.57
1084	HWB10	4	E	R	2	4.48
1085	HWB10	4	E	R	3	4.14
1086	HWB10	4	E	R	4	6.38
1087	HWB6	4	E	R	1	3.63
1088	HWB6	4	E	R	2	3.74
1089	HWB6	4	E	R	3	3.96
1090	HWB6	4	E	R	4	3.68
1091	HWB2	4	E	R	1	4.33
1092	HWB2	4	E	R	2	4.12
1093	HWB2	4	E	R	3	4.33
1094	HWB2	4	E	R	4	3.55
1095	HWL3	4	E	R	1	15.14
1096	HWL3	4	E	R	2	11.57
1097	HWL3	4	E	R	3	10.63

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1098	HWL3	4	E	R	4	10.98
1099	HWL3	4	E	R	5	9.84
1100	HWL3	4	E	R	6	14.97
1101	HWL3	4	E	R	7	15.59
1102	HWL3	4	E	R	8	15.45
1103	HWL3	4	E	R	9	18.46
1104	HWB3	4	E	R/T	1	8.00
1106	HWB3	4	E	R/T	2	5.84
1107	HWB3	4	E	T	3	6.11
1108	HWB3	4	E	T	4	12.46
1109	HWB7	4	E	R/T	1	7.22
1110	HWB7	4	E	R/T	2	7.11
1111	HWB7	4	E	T	3	5.57
1112	HWB7	4	E	T	4	11.58
1113	HWB7	4	E	T	5	14.40
1114	HWB11	4	E	R	1	8.74
1116	HWB11	4	E	R	2	8.73
1117	HWB11	4	E	R	3	8.26
1118	HWB11	4	E	R	4	8.50
1119	NWL5.3	4	E	R	1	10.79
1120	NWL5.3	4	E	R	2	10.45
1121	NWL5.3	4	E	R	3	10.41
1122	NWL4.3	4	E	R	1	12.79
1123	NWL4.3	4	E	R	2	9.55
1124	NWL4.3	4	E	R	3	10.55
1125	NWL3.3	4	E	R	1	15.43
1126	NWL3.3	4	E	R	2	11.56
1127	NWL3.3	4	E	R	3	13.01
1128	NWL3.3	4	E	R	4	10.53
1129	NWL1.3	4	E	R	1	10.75
1131	NWL1.3	4	E	R	2	10.20
1132	NWL1.3	4	E	R	3	11.33
1133	NWL1.3	4	E	R	4	8.81
1134	NWB6.9	4	E	T	1	5.97
1135	NWB6.9	4	E	T	2	5.19
1136	NWB6.9	4	E	T	3	7.17
1137	NWB6.9	4	E	T	4	6.26
1138	NWB6.8	4	E	T	1	6.10
1139	NWB6.8	4	E	T	2	6.57
1140	NWB6.8	4	E	T	3	7.89
1141	NWB6.8	4	E	T	4	8.07
1142	NWB6.7	4	E	T	1	6.14
1143	NWB6.7	4	E	T	2	7.64
1144	NWB6.7	4	E	T	3	6.85
1145	NWB6.7	4	E	T	4	8.36
1146	NWB5.3	4	E	R	1	9.04
1147	NWB5.3	4	E	R	2	8.65
1148	NWB5.3	4	E	R	3	8.79
1149	NWB3.3	4	E	R	1	6.69
1150	NWB3.3	4	E	R	2	6.75
1151	NWB3.3	4	E	R	3	7.73
1152	NWB2.3	4	E	R	1	7.87
1154	NWB2.3	4	E	R	2	7.42
1155	NWB2.3	4	E	R	3	8.47

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1156	NWB2.3	4	E	R	4	8.12
1157	NWB1.3	4	E	R/T	1	7.34
1158	NWB1.3	4	E	R/T	2	6.69
1159	NWB1.3	4	E	R/T	3	8.20
1160	NWB1.3	4	E	R/T	4	7.87
1161	HWL4	4	E	R	1	30.06
1162	HWL4	4	E	R	2	28.65
1163	HWL4	4	E	R	3	26.33
1164	HWL4	4	E	R	3	30.06
1165	HWL4	4	E	R	5	26.50
1166	HWL4	4	E	R	6	27.25
1167	HWL4	4	E	R	7	27.94
1168	HWL4	4	E	R	8	31.85
1169	HWB4	4	E	R/T	1	8.64
1170	HWB4	4	E	R/T	2	7.70
1171	HWB4	4	E	R/T	3	7.20
1172	HWB4	4	E	R/T	4	7.63
1173	HWB8	4	E	R	1	8.57
1175	HWB8	4	E	R/T	2	7.07
1176	HWB8	4	E	R/T	3	6.77
1177	HWB8	4	E	R/T	4	8.41
1179	NWL5.4	4	E	R	1	11.33
1180	NWL5.4	4	E	R	2	10.87
1181	NWL5.4	4	E	R	3	11.41
1182	NWL4.4	4	E	R	1	15.64
1183	NWL4.4	4	E	R	2	21.56
1184	NWL4.4	4	E	R	3	16.87
1185	NWL3.4	4	E	R	1	8.20
1186	NWL3.4	4	E	R	2	10.29
1187	NWL3.4	4	E	R	3	10.82
1188	NWL3.4	4	E	R	4	10.71
1189	NWL1.4	4	E	R	1	10.39
1190	NWL1.4	4	E	R	2	10.53
1191	NWL1.4	4	E	R	3	8.20
1192	NWB7.4	4	E	R	1	6.67
1193	NWB7.4	4	E	R	2	6.98
1194	NWB6.12	4	E	T	1	7.93
1195	NWB6.12	4	E	T	2	7.53
1196	NWB6.12	4	E	T	3	8.49
1197	NWB6.12	4	E	T	4	7.90
1198	NWB6.11	4	E	T	1	6.31
1199	NWB6.11	4	E	T	2	6.88
1200	NWB6.11	4	E	T	3	5.89
1201	NWB6.11	4	E	T	4	6.25
1202	NWB6.10	4	E	T	1	6.58
1203	NWB6.10	4	E	T	2	7.59
1204	NWB6.10	4	E	T	3	6.15
1205	NWB6.10	4	E	T	4	7.42
1206	NWB5.4	4	E	T	1	9.09
1207	NWB5.4	4	E	T	2	6.04
1208	NWB5.4	4	E	T	3	9.32
1209	NWB5.4	4	E	T	4	8.74
1210	NWB4.4	4	E	R/T	1	5.25
1211	NWB4.4	4	E	R/T	2	6.33

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1212	NWB4.4	4	E	R/T	3	7.12
1213	NWB4.4	4	E	R/T	4	8.77
1214	NWB3.4	4	E	R	1	7.78
1215	NWB3.4	4	E	R	2	7.94
1216	NWB2.4	4	E	R	1	8.21
1217	NWB2.4	4	E	R	2	9.37
1218	NWB2.4	4	E	R	3	7.18
1219	NWB1.4	4	E	R	1	8.63
1220	NWB1.4	4	E	R	2	8.75
1221	NWB1.4	4	E	R	3	8.30
1222	NWB1.4	4	E	R	4	7.98
1223	NWB1.1	5	E	R/T	1	3.57
1224	NWB1.1	5	E	R/T	2	4.37
1225	NWB1.1	5	E	R/T	3	4.36
1226	NWB1.1	5	E	R/T	4	4.07
1227	NWB2.1	5	E	R	1	4.06
1229	NWB2.1	5	E	R	2	4.06
1230	NWB2.1	5	E	R	3	4.06
1231	NWB2.1	5	E	R	4	3.63
1232	NWB3.1	5	E	R	1	3.84
1233	NWB3.1	5	E	R	2	4.12
1234	NWB3.1	5	E	R	3	4.59
1235	NWB3.1	5	E	R	4	4.95
1236	NWB4.1	5	E	R	1	4.44
1238	NWB4.1	5	E	R	2	3.86
1239	NWB4.1	5	E	R	3	4.42
1240	NWB4.1	5	E	R	4	4.43
1241	NWB5.1	5	E	R/T	1	4.17
1242	NWB5.1	5	E	R/T	2	4.59
1243	NWB5.1	5	E	R	3	5.18
1244	NWB5.1	5	E	R	4	5.18
1245	NWB5.1	5	E	T	5	4.30
1246	NWB5.1	5	E	R	6	5.21
1247	NWB5.1	5	E	R	7	5.62
1248	NWB5.1	5	E	R/T	8	4.44
1249	NWB5.1	5	E	R/T	9	4.44
1250	NWB5.1	5	E	R/T	10	3.41
1251	NWB6.1	5	E	R/T	1	4.02
1252	NWB6.1	5	E	T	2	3.68
1253	NWB6.1	5	E	T	3	4.06
1254	NWB6.1	5	E	T	4	4.99
1255	NWB6.2	5	E	R/T	1	4.43
1256	NWB6.2	5	E	R/T	2	3.96
1257	NWB6.2	5	E	T	3	4.00
1258	NWB6.2	5	E	T	4	3.62
1259	NWB6.3	5	E	R/T	1	4.50
1260	NWB6.3	5	E	T	2	5.07
1261	NWB6.3	5	E	T	3	5.10
1262	NWB6.3	5	E	T	4	5.10
1263	NWB7.1	5	E	R	1	3.23
1264	NWB7.1	5	E	R	2	3.72
1265	NWB7.1	5	E	R	3	3.12
1266	NWB7.1	5	E	R	4	3.59
1267	NWL1.1	5	E	R	1	4.41

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1269	NWL1.1	5	E	R	2	3.55
1270	NWL1.1	5	E	R	3	3.32
1271	NWL1.1	5	E	R	4	4.10
1272	NWL1.1	5	C	T	5	3.93
1273	NWL3.1	5	E	R	1	3.96
1274	NWL3.1	5	E	R	2	4.44
1275	NWL3.1	5	E	R	3	4.32
1276	NWL3.1	5	E	R	4	3.66
1277	NWL4.1	5	E	R	1	3.68
1279	NWL4.1	5	E	R	2	4.01
1280	NWL4.1	5	E	R	3	4.01
1281	NWL4.1	5	E	R	4	3.59
1282	NWL5.1	5	E	R	1	3.28
1283	NWL5.1	5	E	R	2	3.80
1284	NWL5.1	5	C	T	5	3.41
1285	NWL5.1	5	E	R	3	3.04
1286	NWL5.1	5	E	R	4	3.15
1287	HWL1	5	E	R	1	11.54
1289	HWL1	5	E	R	2	10.73
1290	HWL1	5	E	R	3	5.79
1291	HWL1	5	E	R	4	5.15
1292	HWL1	5	E	R	5	4.31
1293	HWL1	5	E	R	6	4.69
1294	HWL1	5	E	R	7	10.99
1295	HWL1	5	E	R	8	8.71
1296	HWB1	5	E	R/T	1	3.80
1297	HWB1	5	E	R/T	2	3.81
1298	HWB1	5	E	R/T	3	4.05
1299	HWB1	5	E	R/T	4	4.32
1300	HWB5	5	E	R	1	4.32
1302	HWB5	5	E	R	2	3.72
1303	HWB5	5	E	R	3	3.48
1304	HWB5	5	E	R	4	4.65
1305	HWB9	5	E	R	1	3.14
1306	HWB9	5	E	R	2	4.26
1307	HWB9	5	E	R/T	3	2.89
1308	HWB9	5	E	R/T	4	4.03
1309	NWB1.2	5	E	R/T	1	4.27
1310	NWB1.2	5	E	R/T	2	4.56
1311	NWB1.2	5	E	R/T	3	5.09
1312	NWB1.2	5	E	R/T	4	5.26
1313	NWB2.2	5	E	R	1	4.00
1314	NWB2.2	5	E	R	2	4.11
1315	NWB2.2	5	E	R	3	4.11
1316	NWB2.2	5	E	R	4	3.75
1318	NWB3.2	5	E	R	1	4.05
1319	NWB3.2	5	E	R	2	3.83
1320	NWB3.2	5	E	R	3	4.37
1321	NWB3.2	5	E	R	4	4.85
1322	NWB4.2	5	E	R/T	1	5.01
1323	NWB4.2	5	E	R/T	2	5.27
1324	NWB4.2	5	E	T	3	5.27
1325	NWB4.2	5	E	T	4	5.25
1326	NWB5.2	5	E	T	1	4.61

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1327	NWB5.2	5	E	T	2	5.05
1328	NWB5.2	5	E	T	3	4.73
1329	NWB5.2	5	E	T	4	5.53
1330	NWB5.2	5	E	R	5	4.88
1331	NWB5.2	5	E	T	6	4.84
1332	NWB5.2	5	E	T	7	4.73
1333	NWB5.2	5	E	T	8	4.34
1334	NWB5.2	5	E	T	9	4.27
1335	NWB5.2	5	E	R	10	5.66
1336	NWB6.4	5	E	R/T	1	4.87
1337	NWB6.4	5	E	T	2	4.59
1338	NWB6.4	5	E	T	3	4.44
1339	NWB6.4	5	E	T	4	4.90
1340	NWB6.5	5	E	R/T	1	5.51
1341	NWB6.5	5	E	T	2	4.29
1342	NWB6.5	5	E	T	3	4.81
1343	NWB6.5	5	E	T	4	5.34
1344	NWB6.6	5	E	R/T	1	5.29
1346	NWB6.6	5	E	T	2	5.13
1347	NWB6.6	5	E	T	3	5.14
1348	NWB6.6	5	E	T	4	5.14
1349	NWB7.2	5	E	R	1	3.77
1350	NWB7.2	5	E	R	2	4.49
1351	NWB7.2	5	E	R	3	4.16
1352	NWB7.2	5	E	R	4	3.91
1353	NWL5.2	5	E	R	1	7.26
1354	NWL5.2	5	E	R	2	6.99
1355	NWL5.2	5	C	T	5	7.77
1356	NWL5.2	5	C	T	6	5.96
1357	NWL5.2	5	E	R	3	5.27
1358	NWL5.2	5	E	R	4	5.13
1359	NWL4.2	5	E	R	1	7.62
1360	NWL4.2	5	E	R	2	7.00
1361	NWL4.2	5	C	T	5	4.60
1362	NWL4.2	5	E	R	3	5.36
1363	NWL4.2	5	E	R	4	4.86
1364	NWL3.2	5	E	R	1	5.68
1365	NWL3.2	5	E	R	2	5.69
1366	NWL3.2	5	E	R	3	5.69
1367	NWL3.2	5	E	R	4	5.02
1368	NWL1.2	5	E	R	1	5.28
1370	NWL1.2	5	E	R	2	6.15
1371	NWL1.2	5	C	T	5	4.34
1372	NWL1.2	5	E	R	3	5.68
1373	NWL1.2	5	E	R	4	5.24
1374	HWL2	5	E	R	1	7.19
1375	HWL2	5	E	R	2	10.92
1376	HWL2	5	C	T	3	6.50
1377	HWL2	5	E	R	4	9.73
1378	HWL2	5	E	R	5	7.80
1379	HWL2	5	E	R	6	9.00
1380	HWL2	5	C	T	7	6.90
1381	HWL2	5	E	R	8	5.72
1382	HWL2	5	E	R	9	5.73

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1383	HWL2	5	E	R	10	7.86
1384	HWL2	5	E	R	11	4.03
1385	HWL2	5	E	R	12	5.11
1386	HWB10	5	E	R	1	5.53
1387	HWB10	5	E	R/T	2	5.08
1388	HWB10	5	E	T	3	5.79
1389	HWB10	5	E	T	4	7.72
1390	HWB5	5	E	R	1	4.92
1391	HWB5	5	E	R	2	4.46
1392	HWB5	5	E	R	3	4.49
1393	HWB5	5	E	R	4	4.56
1394	HWB2	5	E	R	1	5.03
1395	HWB2	5	E	R	2	5.38
1396	HWB2	5	E	R	3	5.08
1397	HWB2	5	E	R	4	4.79
1398	NWB1.3	5	E	R/T	1	8.60
1399	NWB1.3	5	E	R/T	2	9.46
1400	NWB1.3	5	E	R/T	3	10.04
1401	NWB1.3	5	E	R/T	4	10.59
1402	NWB2.3	5	E	R	1	8.81
1403	NWB2.3	5	E	R	2	7.68
1404	NWB2.3	5	E	R	3	8.07
1405	NWB2.3	5	E	R	4	8.56
1406	NWB3.3	5	E	R	1	11.92
1407	NWB3.3	5	E	R	2	10.79
1408	NWB3.3	5	E	R	3	8.01
1409	NWB3.3	5	E	R	4	9.31
1410	NWB6.7	5	E	T	1	8.68
1411	NWB6.7	5	E	T	2	8.37
1412	NWB6.7	5	E	T	3	9.43
1413	NWB6.7	5	E	T	4	9.78
1414	NWB6.8	5	E	T	1	7.95
1415	NWB6.8	5	E	T	2	7.95
1416	NWB6.8	5	E	T	3	9.31
1417	NWB6.8	5	E	T	4	10.50
1418	NWB6.9	5	E	T	1	8.91
1419	NWB6.9	5	E	T	2	8.05
1420	NWB6.9	5	E	T	3	8.98
1421	NWB6.9	5	E	T	4	9.67
1422	NWL1.3	5	E	R	1	11.47
1423	NWL1.3	5	E	R	2	12.06
1424	NWL1.3	5	E	R	3	10.69
1425	NWL1.3	5	E	R	4	11.50
1426	NWL3.3	5	E	R	1	13.13
1427	NWL3.3	5	E	R	2	14.91
1428	NWL3.3	5	E	R	3	13.83
1429	NWL3.3	5	E	R	4	14.71
1432	NWL5.3	5	E	R	1	13.07
1434	NWL5.3	5	E	R	2	11.07
1435	NWL5.3	5	E	R	3	15.56
1436	NWL5.3	5	E	R	4	14.47
1437	HWB11	5	E	R	1	10.29
1438	HWB11	5	E	R	2	9.90
1439	HWB11	5	E	R	3	9.80

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1440	HWB11	5	E	R	4	10.40
1441	HWB7	5	E	R	1	8.75
1442	HWB7	5	E	R	2	7.19
1443	HWB7	5	E	R	3	6.97
1444	HWB7	5	E	R	4	7.00
1445	HWB3	5	E	R/T	1	10.90
1446	HWB3	5	E	R/T	2	8.91
1447	HWB3	5	E	T	3	9.24
1448	HWB3	5	E	T	4	9.43
1449	HWL3	5	E	R	1	16.65
1451	HWL3	5	E	R	2	14.65
1452	HWL3	5	E	R	3	12.98
1453	HWL3	5	E	R	4	11.39
1454	HWL3	5	E	R	5	10.71
1455	HWL3	5	E	R	6	16.52
1456	HWL3	5	E	R	7	17.66
1457	HWL3	5	E	R	8	16.17
1458	NWB1.4	5	E	R	1	10.71
1460	NWB1.4	5	E	R	2	8.13
1461	NWB1.4	5	E	R	3	9.07
1462	NWB1.4	5	E	R	4	11.12
1463	NWB4.4	5	E	T	1	7.95
1464	NWB4.4	5	E	T	2	9.65
1465	NWB4.4	5	E	T	3	10.10
1466	NWB4.4	5	E	T	4	8.87
1467	NWB5.4	5	E	T	1	10.53
1468	NWB4.4	5	E	T	2	11.42
1469	NWB4.4	5	E	T	3	9.89
1470	NWB4.4	5	E	T	4	9.78
1471	NWB6.10	5	E	T	1	7.07
1472	NWB6.10	5	E	T	2	7.88
1473	NWB6.10	5	E	T	3	9.37
1474	NWB6.10	5	E	T	4	8.13
1475	NWB6.11	5	E	T	1	7.32
1476	NWB6.11	5	E	T	2	6.46
1477	NWB6.11	5	E	T	3	7.50
1478	NWB6.11	5	E	T	4	7.46
1479	NWB6.12	5	E	T	1	7.48
1480	NWB6.12	5	E	T	2	7.72
1481	NWB6.12	5	E	T	3	7.72
1482	NWB6.12	5	E	T	4	7.93
1483	NWB7.4	5	E	R	1	9.02
1485	NWB7.4	5	E	R	2	9.38
1486	NWL1.4	5	E	R	1	11.40
1487	NWL1.4	5	E	R	2	11.92
1488	NWL1.4	5	E	R	3	14.92
1489	NWL1.4	5	E	R	4	18.25
1490	NWL3.4	5	E	R	1	11.28
1491	NWL3.4	5	E	R	2	11.90
1492	NWL3.4	5	E	R	3	12.52
1493	NWL4.4	5	E	R	1	19.65
1494	NWL4.4	5	E	R	2	21.96
1495	NWL4.4	5	E	R	3	14.34
1496	NWL4.4	5	E	R	4	16.79

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1497	NWL5.4	5	E	R	1	13.48
1498	NWL5.4	5	E	R	2	12.78
1499	HWB12	5	E	R	1	7.26
1500	HWB12	5	E	R	2	8.17
1501	HWB12	5	E	R	3	8.57
1502	HWB8	5	E	R/T	1	8.17
1503	HWB8	5	E	R/T	2	8.24
1504	HWB8	5	E	R/T	3	7.30
1505	HWB8	5	E	R/T	4	7.55
1506	HWB4	5	E	R	1	9.33
1507	HWB4	5	E	R/T	2	8.34
1508	HWB4	5	E	R/T	3	8.08
1509	HWB4	5	E	R/T	4	7.68
1510	HWL4	5	E	R	1	30.97
1511	HWL4	5	E	R	2	26.79
1512	HWL4	5	E	R	3	29.46
1513	HWL4	5	E	R	4	26.81
1514	HWL4	5	E	R	5	26.14
1515	HWL4	5	E	R	6	26.81
1516	HWL4	5	E	R	7	30.69
1517	HWL4	5	E	R	8	31.56
1519	NWB7.1	6	E	R	1	3.16
1520	NWB7.1	6	E	R	2	3.55
1521	NWB7.1	6	E	R	3	3.75
1522	NWB7.1	6	E	R	4	3.16
1523	NWB7.1	6	E	R	5	3.66
1524	NWB7.1	6	E	R	6	3.84
1525	NWB7.1	6	E	R	7	4.13
1526	NWB7.1	6	E	R	8	4.26
1527	NWB6.3	6	E	T	1	4.18
1528	NWB6.3	6	E	T	2	3.98
1529	NWB6.3	6	E	T	3	4.01
1530	NWB6.3	6	E	T	4	3.96
1531	NWB6.3	6	E	T	5	3.89
1532	NWB6.3	6	E	T	6	4.48
1533	NWB6.3	6	E	T	7	4.82
1534	NWB6.3	6	E	T	8	4.89
1535	NWB6.2	6	E	R/T	1	3.73
1536	NWB6.2	6	E	T	2	3.94
1537	NWB6.2	6	E	T	3	4.31
1538	NWB6.2	6	E	T	4	3.74
1539	NWB6.2	6	E	R/T	5	3.88
1540	NWB6.2	6	E	T	6	4.20
1541	NWB6.2	6	E	T	7	4.20
1542	NWB6.2	6	E	T	8	4.08
1543	NWB6.1	6	E	R/T	1	4.01
1544	NWB6.1	6	E	T	2	3.84
1545	NWB6.1	6	E	T	3	4.01
1546	NWB6.1	6	E	T	4	3.92
1547	NWB6.1	6	E	R/T	5	4.99
1548	NWB6.1	6	E	T	6	4.20
1549	NWB6.1	6	E	T	7	3.79
1550	NWB6.1	6	E	T	8	4.52
1551	NWB5.1	6	E	R/T	1	4.29

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1552	NWB5.1	6	E	R	2	5.14
1553	NWB5.1	6	E	R	3	5.01
1554	NWB5.1	6	E	R	4	5.05
1555	NWB5.1	6	E	T	5	3.87
1556	NWB5.1	6	E	R	6	4.35
1557	NWB5.1	6	E	R	7	4.67
1558	NWB5.1	6	E	R/T	8	4.09
1559	NWB5.1	6	E	T	9	5.09
1560	NWB5.1	6	E	R/T	10	4.35
1561	NWB5.1	6	E	R/T	11	4.11
1562	NWB5.1	6	E	R/T	12	5.43
1563	NWB5.1	6	E	R	13	5.70
1564	NWB5.1	6	E	R	14	5.09
1565	NWB5.1	6	E	T	15	4.59
1566	NWB5.1	6	E	R	16	5.53
1567	NWB5.1	6	E	R	17	5.53
1568	NWB5.1	6	E	R/T	18	5.17
1569	NWB5.1	6	E	T	19	5.51
1570	NWB5.1	6	E	R/T	20	4.14
1571	NWB4.1	6	E	T	1	4.96
1572	NWB4.1	6	E	T	2	4.84
1573	NWB4.1	6	E	T	3	4.50
1574	NWB4.1	6	E	T	4	5.47
1575	NWB4.1	6	E	T	5	5.70
1576	NWB4.1	6	E	T	6	4.73
1577	NWB4.1	6	E	T	7	4.24
1578	NWB4.1	6	E	T	8	4.44
1579	NWB3.1	6	E	R	1	4.44
1581	NWB3.1	6	E	R	2	3.75
1582	NWB3.1	6	E	R	3	4.39
1583	NWB3.1	6	E	R	4	4.61
1584	NWB3.1	6	E	R	5	4.55
1585	NWB3.1	6	E	R	6	4.05
1586	NWB3.1	6	E	R	7	4.29
1587	NWB3.1	6	E	R	8	4.55
1588	NWB2.1	6	E	R	1	4.32
1589	NWB2.1	6	E	R	2	4.76
1590	NWB2.1	6	E	R	3	5.08
1591	NWB2.1	6	E	R	4	5.41
1592	NWB2.1	6	E	R	5	4.52
1593	NWB2.1	6	E	R	6	4.33
1594	NWB2.1	6	E	R	7	4.06
1595	NWB2.1	6	E	R	8	4.06
1596	NWB1.1	6	E	R	1	4.14
1597	NWB1.1	6	E	R/T	2	4.49
1598	NWB1.1	6	E	R/T	3	4.05
1599	NWB1.1	6	E	R/T	4	4.18
1600	NWB1.1	6	E	R	5	4.67
1601	NWB1.1	6	E	R/T	6	4.51
1602	NWB1.1	6	E	R/T	7	4.23
1603	NWB1.1	6	E	R/T	8	4.45
1604	HWB5	6	E	R	1	4.51
1605	HWB5	6	E	R	2	4.67
1606	HWB5	6	E	R	3	4.92

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1607	HWB5	6	E	R	4	5.18
1608	HWB5	6	E	R	5	3.82
1609	HWB5	6	E	R	6	4.32
1610	HWB5	6	E	R	7	4.47
1611	HWB5	6	E	R	8	4.66
1665	HWB1	6	E	T	1	3.96
1666	HWB1	6	E	T	2	3.68
1667	HWB1	6	E	T	3	3.90
1668	HWB1	6	E	T	4	4.16
1669	HWB1	6	E	T	5	3.34
1670	HWB1	6	E	T	6	3.95
1671	HWB1	6	E	T	7	3.96
1672	HWB1	6	E	T	8	4.23
1673	HWB9	6	E	R/T	1	4.85
1674	HWB9	6	E	R/T	2	4.81
1675	HWB9	6	E	R/T	3	3.35
1676	HWB9	6	E	R	4	4.07
1677	HWB9	6	E	R/T	5	5.02
1678	HWB9	6	E	R/T	6	3.55
1679	HWB9	6	E	R/T	7	4.71
1680	HWB9	6	E	R	8	4.05
1612	NWL5.1	6	E	R	1	3.66
1613	NWL5.1	6	E	R	2	3.66
1614	NWL5.1	6	E	R	3	4.70
1615	NWL5.1	6	E	R	4	3.47
1616	NWL5.1	6	E	R	5	4.43
1617	NWL5.1	6	E	R	6	4.34
1618	NWL5.1	6	E	R	7	4.55
1619	NWL5.1	6	E	R	8	4.67
1620	NWL4.1	6	E	R	1	3.50
1621	NWL4.1	6	E	R	2	4.21
1622	NWL4.1	6	E	R	3	4.38
1623	NWL4.1	6	E	R	4	4.19
1624	NWL4.1	6	E	R	5	3.96
1625	NWL4.1	6	E	R	6	4.21
1626	NWL4.1	6	E	R	7	3.76
1627	NWL4.1	6	E	R	8	3.39
1628	NWL3.1	6	E	R	1	3.65
1629	NWL3.1	6	E	R	2	4.17
1630	NWL3.1	6	E	R	3	4.27
1631	NWL3.1	6	E	R	4	4.44
1633	NWL3.1	6	E	R	5	4.68
1634	NWL3.1	6	E	R	6	4.35
1635	NWL3.1	6	E	R	7	4.10
1636	NWL3.1	6	E	R	8	4.39
1637	NWL1.1	6	E	R	1	3.91
1638	NWL1.1	6	E	R	2	3.92
1639	NWL1.1	6	E	R	3	2.93
1640	NWL1.1	6	E	R	4	3.25
1641	NWL1.1	6	E	R	5	4.09
1642	NWL1.1	6	E	R	6	3.90
1643	NWL1.1	6	E	R	7	3.05
1644	NWL1.1	6	E	R	8	4.08
1645	HWL1	6	E	R	1	10.83

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1646	HWL1	6	E	R	2	14.47
1647	HWL1	6	E	R	3	6.19
1648	HWL1	6	E	R	4	5.33
1649	HWL1	6	E	R	5	5.77
1650	HWL1	6	E	R	6	5.15
1651	HWL1	6	E	R	7	4.93
1652	HWL1	6	E	R	8	6.01
1653	HWL1	6	E	R	9	7.52
1654	HWL1	6	E	R	10	9.89
1655	HWL1	6	E	R	11	8.87
1656	HWL1	6	E	R	12	7.71
1657	HWL1	6	E	R	13	4.84
1658	HWL1	6	E	R	14	4.45
1659	HWL1	6	E	R	15	4.46
1660	HWL1	6	E	R	16	5.65
1661	HWL1	6	E	R	17	5.66
1662	HWL1	6	E	R	18	7.33
1663	HWL1	6	E	R	19	11.48
1664	HWL1	6	E	R	20	12.04
1681	HWL2	6	E	R	1	6.27
1682	HWL2	6	E	R	2	7.38
1683	HWL2	6	E	R	3	4.92
1684	HWL2	6	E	R	4	7.48
1685	HWL2	6	E	R	5	8.45
1686	HWL2	6	E	R	6	6.98
1687	HWL2	6	E	R	7	9.22
1688	HWL2	6	C	T	8	7.02
1689	HWL2	6	E	R	9	7.23
1690	HWL2	6	E	R	10	6.90
1691	HWL2	6	E	R	11	6.77
1692	HWL2	6	E	R	12	6.88
1693	HWL2	6	E	R	13	6.15
1694	HWL2	6	E	R	14	6.35
1695	HWL2	6	E	R	15	7.66
1696	HWL2	6	E	R	16	6.67
1697	HWL2	6	E	R	17	8.17
1698	HWL2	6	C	T	18	8.30
1699	HWL2	6	E	R	19	8.78
1700	HWL2	6	E	R	20	8.27
1701	HWB2	6	E	R	1	5.24
1702	HWB2	6	E	R	2	5.49
1703	HWB2	6	E	R	3	4.83
1704	HWB2	6	E	R	4	5.22
1705	HWB2	6	E	R	5	4.56
1706	HWB2	6	E	R	6	4.88
1707	HWB2	6	E	R	7	4.63
1708	HWB2	6	E	R	8	5.16
1709	HWB6	6	E	R	1	5.68
1710	HWB6	6	E	R	2	5.61
1711	HWB6	6	E	R	3	5.17
1712	HWB6	6	E	R	4	4.75
1713	HWB6	6	E	R	5	5.78
1715	HWB6	6	E	R	6	6.22
1716	HWB6	6	E	R	7	6.15

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1717	HWB6	6	E	R	8	5.95
1718	HWB10	6	E	T	1	7.19
1719	HWB10	6	E	T	2	5.83
1720	HWB10	6	E	R/T	3	5.50
1721	HWB10	6	E	R	4	4.98
1722	HWB10	6	E	T	5	7.18
1723	HWB10	6	E	T	6	6.08
1724	HWB10	6	E	R/T	7	6.08
1725	HWB10	6	E	R	8	5.63
1726	NWL1.2	6	E	R	1	4.95
1727	NWL1.2	6	E	R	2	5.32
1728	NWL1.2	6	E	R	3	6.36
1729	NWL1.2	6	E	R	4	7.09
1730	NWL1.2	6	E	R	5	6.31
1731	NWL1.2	6	E	R	6	5.93
1732	NWL1.2	6	E	R	7	6.34
1733	NWL1.2	6	E	R	8	6.84
1734	NWL3.2	6	E	R	1	6.27
1736	NWL3.2	6	E	R	2	5.82
1737	NWL3.2	6	E	R	3	6.06
1738	NWL3.2	6	E	R	4	7.52
1739	NWL3.2	6	E	R	5	6.21
1740	NWL3.2	6	E	R	6	5.66
1741	NWL3.2	6	E	R	7	5.69
1742	NWL3.2	6	E	R	8	6.42
1743	NWL4.2	6	E	R	1	6.23
1744	NWL4.2	6	E	R	2	6.54
1745	NWL4.2	6	E	R	3	7.01
1746	NWL4.2	6	E	R	4	5.61
1747	NWL4.2	6	C	T	5	4.81
1748	NWL4.2	6	E	R	6	6.69
1749	NWL4.2	6	E	R	7	7.00
1750	NWL4.2	6	E	R	8	6.43
1751	NWL4.2	6	E	R	9	5.35
1752	NWL4.2	6	C	T	10	5.36
1753	NWL5.2	6	E	R	1	6.00
1755	NWL5.2	6	E	R	2	6.25
1756	NWL5.2	6	E	R	3	5.66
1757	NWL5.2	6	E	R	4	6.08
1758	NWL5.2	6	C	T	5	5.38
1759	NWL5.2	6	E	R	6	5.96
1760	NWL5.2	6	E	R	7	6.59
1761	NWL5.2	6	C	T	10	6.30
1762	NWL5.2	6	E	R	8	6.45
1763	NWL5.2	6	E	R	9	6.45
1764	NWB1.2	6	e	R	1	3.82
1765	NWB1.2	6	E	R	2	3.47
1766	NWB1.2	6	E	R/T	3	4.14
1767	NWB1.2	6	E	R/T	4	4.84
1768	NWB2.2	6	E	R	1	3.42
1769	NWB2.2	6	E	R	2	3.85
1770	NWB2.2	6	E	R	3	4.28
1771	NWB2.2	6	E	R	4	3.89
1772	NWB2.2	6	E	R	5	3.62

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1773	NWB2.2	6	E	R	6	3.82
1774	NWB2.2	6	E	R	7	3.84
1775	NWB2.2	6	E	R	8	4.24
1776	NWB3.2	6	E	R	1	4.58
1777	NWB3.2	6	E	R	2	4.38
1778	NWB3.2	6	E	R	3	4.39
1779	NWB3.2	6	E	R	4	4.06
1780	NWB3.2	6	E	R	5	4.19
1781	NWB3.2	6	E	R	6	4.63
1782	NWB3.2	6	E	R	7	4.10
1783	NWB3.2	6	E	R	8	5.05
1784	NWB4.2	6	E	R/T	1	4.31
1786	NWB4.2	6	E	R/T	2	4.57
1787	NWB4.2	6	E	T	3	4.79
1788	NWB4.2	6	E	T	4	4.18
1789	NWB4.2	6	E	R/T	5	4.46
1790	NWB4.2	6	E	R/T	6	5.62
1791	NWB4.2	6	E	T	7	5.72
1792	NWB4.2	6	E	T	8	5.46
1793	NWB5.2	6	E	T	1	4.81
1794	NWB5.2	6	E	T	2	5.04
1795	NWB5.2	6	E	T	3	5.40
1796	NWB5.2	6	E	T	4	5.08
1797	NWB5.2	6	E	R	5	5.12
1798	NWB5.2	6	E	T	6	5.56
1799	NWB5.2	6	E	T	7	5.22
1800	NWB5.2	6	E	T	8	4.82
1801	NWB5.2	6	E	T	9	5.23
1802	NWB5.2	6	E	R/T	10	4.59
1803	NWB5.2	6	E	T	11	4.97
1804	NWB5.2	6	E	T	12	4.81
1805	NWB5.2	6	E	T	13	5.36
1806	NWB5.2	6	E	T	14	5.22
1807	NWB5.2	6	E	R	15	5.47
1808	NWB5.2	6	E	T	16	5.62
1809	NWB5.2	6	E	T	17	5.88
1810	NWB5.2	6	E	T	18	5.89
1811	NWB5.2	6	E	T	19	5.69
1812	NWB5.2	6	E	R/T	20	5.58
1813	NWB6.4	6	E	R/T	1	4.48
1814	NWB6.4	6	E	T	2	4.57
1815	NWB6.4	6	E	T	3	4.81
1816	NWB6.4	6	E	T	4	5.24
1817	NWB6.4	6	E	T	5	4.50
1818	NWB6.4	6	E	T	6	4.92
1819	NWB6.4	6	E	T	7	4.59
1820	NWB6.4	6	E	T	8	4.93
1821	NWB6.5	6	E	T	1	4.97
1823	NWB6.5	6	E	T	2	4.79
1824	NWB6.5	6	E	T	3	4.81
1825	NWB6.5	6	E	T	4	5.37
1826	NWB6.5	6	E	T	5	5.85
1827	NWB6.5	6	E	T	6	5.46
1828	NWB6.5	6	E	T	7	5.85

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1829	NWB6.5	6	E	T	8	5.37
1830	NWB6.6	6	E	T	1	5.59
1831	NWB6.6	6	E	T	2	4.69
1832	NWB6.6	6	E	T	3	4.79
1833	NWB6.6	6	E	T	4	4.78
1834	NWB6.6	6	E	T	5	5.30
1835	NWB6.6	6	E	T	6	5.28
1836	NWB6.6	6	E	T	7	4.90
1837	NWB6.6	6	E	T	8	4.29
1838	NWB7.2	6	E	R	1	4.49
1839	NWB7.2	6	E	R	2	4.77
1840	NWB7.2	6	E	R	3	4.41
1841	NWB7.2	6	E	R	4	4.58
1842	NWB7.2	6	E	R	5	5.17
1843	NWB7.2	6	E	R	6	5.19
1844	NWB7.2	6	E	R	7	4.78
1845	NWB7.2	6	E	R	8	5.14
1846	HWL3	6	E	R	1	19.50
1847	HWL3	6	E	R	2	14.78
1848	HWL3	6	E	R	3	11.65
1849	HWL3	6	E	R	4	12.06
1850	HWL3	6	E	R	5	12.91
1851	HWL3	6	E	R	6	16.70
1852	HWL3	6	E	R	7	19.88
1853	HWL3	6	E	R	8	17.24
1854	HWL3	6	E	R	9	14.48
1855	HWL3	6	E	R	10	18.23
1856	HWL3	6	E	R	11	17.12
1857	HWL3	6	E	R	12	17.44
1858	HWL3	6	E	R	13	15.25
1859	HWL3	6	E	R	14	12.95
1860	HWL3	6	E	R	15	14.54
1861	HWL3	6	E	R	16	17.07
1862	HWL3	6	E	R	17	18.69
1863	HWL3	6	E	R	18	23.02
1864	HWL3	6	E	R	19	14.02
1865	HWL3	6	E	R	20	13.76
1866	HWB3	6	E	T	1	11.80
1867	HWB3	6	E	T	2	8.94
1868	HWB3	6	E	R/T	3	7.55
1869	HWB3	6	E	R/T	4	9.76
1870	HWB3	6	E	T	5	13.25
1871	HWB3	6	E	T	6	8.29
1872	HWB3	6	E	R/T	7	6.21
1873	HWB3	6	E	R/T	8	9.51
1874	HWB7	6	E	R/T	1	12.35
1875	HWB7	6	E	R/T	2	6.75
1876	HWB7	6	E	R/T	3	7.25
1877	HWB7	6	E	R/T	4	8.05
1878	HWB7	6	E	R/T	5	14.17
1879	HWB7	6	E	R/T	6	8.15
1880	HWB7	6	E	R/T	7	8.04
1881	HWB7	6	E	R/T	8	7.27
1882	HWB11	6	E	R	1	9.59

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1883	HWB11	6	E	R	2	9.98
1884	HWB11	6	E	R	3	8.85
1885	HWB11	6	E	R	4	9.37
1886	HWB11	6	E	R	5	9.41
1887	HWB11	6	E	R	6	8.75
1888	HWB11	6	E	R	7	10.03
1889	HWB11	6	E	R	8	9.64
1890	NWL5.3	6	E	R	4	10.91
1891	NWL5.3	6	E	R	5	12.03
1892	NWL5.3	6	E	R	6	11.58
1893	NWL5.3	6	E	R	1	11.97
1894	NWL5.3	6	E	R	2	15.38
1895	NWL5.3	6	E	R	3	12.57
1896	NWL3.3	6	E	R	4	10.39
1897	NWL3.3	6	E	R	5	14.27
1898	NWL3.3	6	E	R	6	14.76
1899	NWL3.3	6	E	R	1	14.56
1900	NWL3.3	6	E	R	2	14.33
1901	NWL3.3	6	E	R	3	10.98
1902	NWL1.3	6	E	R	5	18.58
1904	NWL1.3	6	E	R	6	13.44
1905	NWL1.3	6	E	R	7	13.02
1906	NWL1.3	6	E	R	8	11.37
1907	NWL1.3	6	E	R	1	16.84
1908	NWL1.3	6	E	R	2	12.52
1909	NWL1.3	6	E	R	3	11.74
1910	NWL1.3	6	E	R	4	11.28
1911	NWB1.3	6	E	R	1	9.20
1912	NWB1.3	6	E	R/T	2	11.14
1913	NWB1.3	6	E	R/T	3	10.09
1914	NWB1.3	6	E	R/T	4	9.25
1915	NWB1.3	6	E	R	5	12.69
1916	NWB1.3	6	E	R/T	6	9.17
1917	NWB1.3	6	E	R/T	7	10.52
1918	NWB1.3	6	E	R/T	8	9.33
1919	NWB2.3	6	E	R	1	10.65
1920	NWB2.3	6	E	R	2	10.49
1921	NWB2.3	6	E	R	3	9.23
1922	NWB2.3	6	E	R	4	9.52
1923	NWB2.3	6	E	R	5	9.41
1924	NWB2.3	6	E	R	6	7.63
1925	NWB2.3	6	E	R	7	8.13
1926	NWB2.3	6	E	R	8	8.23
1927	NWB3.3	6	E	R	1	10.56
1929	NWB3.3	6	E	R	2	8.93
1930	NWB3.3	6	E	R	3	9.15
1931	NWB3.3	6	E	R	4	9.68
1932	NWB3.3	6	E	R	5	11.58
1933	NWB3.3	6	E	R	6	11.71
1934	NWB3.3	6	E	R	7	10.50
1935	NWB3.3	6	E	R	8	11.11
1936	NWB5.3	6	E	R	1	8.11
1937	NWB5.3	6	E	R	2	8.76
1938	NWB5.3	6	E	R/T	3	9.27

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1939	NWB5.3	6	E	T	4	9.18
1940	NWB5.3	6	E	R	5	9.41
1941	NWB5.3	6	E	R	6	9.02
1942	NWB5.3	6	E	R	7	10.37
1943	NWB5.3	6	E	R	8	8.87
1944	NWB5.3	6	E	R	9	9.35
1945	NWB5.3	6	E	R/T	10	11.78
1946	NWB5.3	6	E	R/T	11	11.46
1948	NWB6.7	6	E	R	1	7.47
1950	NWB6.7	6	E	R	2	7.06
1951	NWB6.7	6	E	R	3	7.49
1952	NWB6.7	6	E	R	4	7.94
1953	NWB6.7	6	E	R	5	9.20
1954	NWB6.7	6	E	R	6	8.31
1955	NWB6.7	6	E	R	7	8.79
1956	NWB6.7	6	E	R	8	7.88
1957	NWB6.8	6	E	T	1	9.10
1958	NWB6.8	6	E	T	2	8.63
1959	NWB6.8	6	E	T	3	7.61
1960	NWB6.8	6	E	T	4	8.05
1961	NWB6.8	6	E	T	5	9.24
1962	NWB6.8	6	E	T	6	8.83
1963	NWB6.8	6	E	T	7	9.36
1964	NWB6.8	6	E	T	8	7.27
1965	NWB6.9	6	E	T	1	9.35
1966	NWB6.9	6	E	T	2	8.86
1967	NWB6.9	6	E	T	3	8.91
1968	NWB6.9	6	E	T	4	9.07
1969	NWB6.9	6	E	T	5	9.52
1970	NWB6.9	6	E	T	6	9.09
1971	NWB6.9	6	E	T	7	8.67
1972	NWB6.9	6	E	T	8	8.41
1973	NWB1.4	6	E	R	1	10.14
1974	NWB1.4	6	E	R	2	10.57
1975	NWB1.4	6	E	R/T	3	10.59
1976	NWB1.4	6	E	R/T	4	10.64
1977	NWB1.4	6	E	R	5	12.84
1978	NWB1.4	6	E	R	6	10.32
1979	NWB1.4	6	E	R/T	7	10.51
1980	NWB1.4	6	E	R/T	8	8.68
1981	NWB3.4	6	E	R	1	9.80
1982	NWB3.4	6	E	R	2	10.90
1983	NWB3.4	6	E	R	3	11.31
1984	NWB3.4	6	E	R	4	8.54
1985	NWB3.4	6	E	R	5	8.93
1986	NWB3.4	6	E	R	6	8.67
1987	NWB4.4	6	E	R	1	9.34
1988	NWB4.4	6	E	R/T	2	10.94
1989	NWB4.4	6	E	R/T	3	10.51
1990	NWB4.4	6	E	T	4	8.75
1991	NWB4.4	6	E	R	5	11.06
1992	NWB4.4	6	E	R/T	6	10.42
1993	NWB4.4	6	E	R/T	7	9.22
1994	NWB4.4	6	E	T	8	7.83

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1995	NWB5.4	6	E	T	1	10.06
1996	NWB5.4	6	E	T	2	9.92
1997	NWB5.4	6	E	T	3	9.51
1998	NWB5.4	6	E	T	4	11.68
1999	NWB5.4	6	E	T	5	11.10
2000	NWB5.4	6	E	T	6	9.83
2001	NWB5.4	6	E	T	7	11.19
2002	NWB5.4	6	E	T	8	11.50
2003	NWB5.4	6	E	T	9	9.84
2004	NWB5.4	6	E	T	10	10.19
2005	NWB6.10	6	E	T	1	7.49
2006	NWB6.10	6	E	T	2	8.64
2007	NWB6.10	6	E	T	3	9.55
2008	NWB6.10	6	E	T	4	10.12
2009	NWB6.10	6	E	T	5	12.06
2010	NWB6.10	6	E	T	6	11.15
2011	NWB6.10	6	E	T	7	11.02
2012	NWB6.10	6	E	T	8	10.27
2013	NWB6.11	6	E	T	1	8.55
2014	NWB6.11	6	E	T	2	8.63
2015	NWB6.11	6	E	T	3	9.29
2016	NWB6.11	6	E	T	4	9.68
2017	NWB6.11	6	E	T	5	9.33
2018	NWB6.11	6	E	T	6	9.35
2019	NWB6.11	6	E	T	7	9.30
2020	NWB6.11	6	E	T	8	9.80
2021	NWB6.12	6	E	T	1	9.35
2022	NWB6.12	6	E	T	2	11.34
2023	NWB6.12	6	E	T	3	10.45
2024	NWB6.12	6	E	T	4	9.68
2025	NWB6.12	6	E	T	5	9.62
2026	NWB6.12	6	E	T	6	9.37
2027	NWB6.12	6	E	T	7	9.38
2028	NWB6.12	6	E	T	8	9.03
2029	NWL3.4	6	E	R	1	11.16
2030	NWL3.4	6	E	R	2	12.48
2031	NWL3.4	6	E	R	3	12.15
2032	NWL3.4	6	E	R	4	10.69
2033	NWL3.4	6	E	R	5	12.48
2034	NWL3.4	6	E	R	6	13.43
2035	NWL3.4	6	E	R	7	17.21
2036	NWL3.4	6	E	R	8	13.87
2037	NWL1.4	6	E	R	1	11.19
2038	NWL1.4	6	E	R	2	10.69
2039	NWL1.4	6	E	R	3	12.96
2040	NWL1.4	6	E	R	4	13.73
2041	NWL1.4	6	E	R	5	11.67
2042	NWL1.4	6	E	R	6	11.96
2043	NWL1.4	6	E	R	7	16.99
2044	NWL1.4	6	E	R	8	15.42
2045	NWL5.4	6	E	R	1	21.30
2046	NWL5.4	6	E	R	2	17.66
2047	NWL5.4	6	E	R	3	24.37
2048	NWL5.4	6	E	R	4	16.05

Appendix A, Table 1: Raw Data

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
2049	NWL4.4	6	E	R	1	17.18
2050	NWL4.4	6	E	R	2	21.01
2051	NWL4.4	6	E	R	3	21.13
2052	NWL4.4	6	E	R	4	17.68
2053	NWL4.4	6	E	R	5	17.27
2054	NWL4.4	6	E	R	6	19.37
2055	HWL4	6	E	R	1	30.24
2056	HWL4	6	E	R	2	28.55
2057	HWL4	6	E	R	3	32.78
2058	HWL4	6	E	R	4	32.03
2059	HWL4	6	E	R	5	27.01
2060	HWL4	6	E	R	6	28.23
2061	HWL4	6	E	R	7	30.28
2062	HWL4	6	E	R	8	30.61
2063	HWL4	6	E	R	9	32.51
2064	HWL4	6	E	R	10	33.11
2065	HWL4	6	E	R	11	30.83
2066	HWL4	6	E	R	12	30.44
2067	HWL4	6	E	R	13	27.44
2068	HWL4	6	E	R	14	34.60
2069	HWB12	6	E	R	1	9.56
2070	HWB12	6	E	R	2	10.29
2071	HWB12	6	E	R	3	9.39
2072	HWB12	6	E	R	4	9.50
2073	HWB12	6	E	R	5	10.69
2074	HWB12	6	E	R	6	10.38
2075	HWB12	6	E	R	7	10.12
2076	HWB12	6	E	R	8	10.23
2077	HWB8	6	E	T	1	15.43
2078	HWB8	6	E	T	2	8.89
2079	HWB8	6	E	R/T	3	9.03
2080	HWB8	6	E	R/T	4	8.34
2081	HWB8	6	E	T	5	8.49
2082	HWB8	6	E	T	6	8.87
2083	HWB8	6	E	R/T	7	8.40
2084	HWB8	6	E	R/T	8	15.40
2085	HWB4	6	E	R	1	11.59
2086	HWB4	6	E	R/T	2	9.75
2087	HWB4	6	E	R/T	3	7.64
2088	HWB4	6	E	T	4	14.07
2089	HWB4	6	E	R	5	12.80
2090	HWB4	6	E	R/T	6	10.17
2091	HWB4	6	E	R/T	7	9.09
2092	HWB4	6	E	T	8	13.91

Appendix A, Table 2: Outlier Data from Interquartile Range Analysis

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
5	HWL1	1	E	R	5	28.12
22	NWL1.1	1	E	R	2	1.15
82	NWB7.1	1	E	R	4	4.69
113	NWL3.2	1	E	R	1	5.25
120	NWL4.2	1	E	R	4	2.14
181	HWB3	1	E	T	3	9.79
210	NWB1.3	1	E	R/T	3	12.87
212	NWB2.3	1	E	R	1	14.03
215	NWB2.3	1	E	R	4	15.86
255	HWB8	1	E	T	4	12.27
305	NWB5.4	1	E	T	9	8.25
333	HWB5	2	E	R	4	2.57
336	HWB1	2	E	R/T	3	4.84
346	NWL5.1	2	C	T	5	4.1
350	NWL4.1	2	E	R	4	4.3
381	NWB5.1	2	E	R	6	6.55
385	NWB5.1	2	E	R/T	10	6.3
435	NWL4.2	2	E	R	1	7.59
444	NWL5.2	2	E	T	5	7.16
514	NWL5.3	2	E	R	3	12.7
518	NWL4.3	2	E	R	1	11.55
521	NWL3.3	2	C	T	3	5.8
523	NWL1.3	2	E	R	1	12.32
526	NWL1.3	2	C	T	4	4.52
567	HWL4	2	E	R	8	45.62
576	HWB12	2	E	R	1	25.23
611	NWB5.4	2	E	R	4	9.91
665	NWL3.1	3	E	R	4	3.84
723	HWB10	3	E	R/T	4	6.05
909	NWB5.4	3	E	R/T	4	10.25
912	NWB5.4	3	E	R	7	11.65
985	NWL5.1	4	E	R	1	2.52
1075	HWL2	4	E	R	3	8.63
1086	HWB10	4	E	R	4	6.38
1108	HWB3	4	E	T	4	12.46
1112	HWB7	4	E	T	4	11.58
1113	HWB7	4	E	T	5	14.4
1125	NWL3.3	4	E	R	1	15.43
1182	NWL4.4	4	E	R	1	15.64
1183	NWL4.4	4	E	R	2	21.56
1184	NWL4.4	4	E	R	3	16.87
1185	NWL3.4	4	E	R	1	8.2
1191	NWL1.4	4	E	R	3	8.2
1247	NWB5.1	5	E	R	7	5.62
1389	HWB10	5	E	T	4	7.72
1406	NWB3.3	5	E	R	1	11.92

Appendix A, Table 2: Outlier Data from Interquartile Range Analysis

Result_ID	Sample_Name	Week	Result_Loc	Result_Grain	Result_Number	Result
1506	HWB4	5	E	R	1	9.33
1870	HWB3	6	E	T	5	13.25
1878	HWB7	6	E	R/T	5	14.17
1912	NWB1.3	6	E	R/T	2	11.14
1915	NWB1.3	6	E	R	5	12.69
1932	NWB3.3	6	E	R	5	11.58
1933	NWB3.3	6	E	R	6	11.71
1935	NWB3.3	6	E	R	8	11.11
1945	NWB5.3	6	E	R/T	10	11.78
1946	NWB5.3	6	E	R/T	11	11.46
1950	NWB6.7	6	E	R	2	7.06
1977	NWB1.4	6	E	R	5	12.84
2077	HWB8	6	E	T	1	15.43
2084	HWB8	6	E	R/T	8	15.4
2088	HWB4	6	E	T	4	14.07
2092	HWB4	6	E	T	8	13.91

Appendix A, Table 3: T-Tests Comparison Data

Comparison:Treatment

1NL ≤ 3NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.008125	13.126
Variance	0.219860887	4.591204211
Observations	32	20
Hypothesized Mean Difference	0	
df	20	
t Stat	-18.75173902	
P(T<=t) one-tail	1.84113E-14	
t Critical one-tail	1.724718218	
P(T<=t) two-tail	3.68225E-14	
t Critical two-tail	2.085963441	

1HL ≤ 3HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	7.429	16.0645
Variance	8.414556842	8.628352368
Observations	20	20
Hypothesized Mean Difference	0	
df	38	
t Stat	-9.354716298	
P(T<=t) one-tail	1.05396E-11	
t Critical one-tail	1.685954461	
P(T<=t) two-tail	2.10792E-11	
t Critical two-tail	2.024394147	

1NB ≤ 3NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.411428571	9.001176471
Variance	0.313773838	0.707058588
Observations	84	51
Hypothesized Mean Difference	0	
df	77	
t Stat	-34.59721775	
P(T<=t) one-tail	5.63296E-49	
t Critical one-tail	1.664884538	
P(T<=t) two-tail	1.12659E-48	
t Critical two-tail	1.991254363	

Appendix A, Table 3: T-Tests Comparison Data

Comparison:Treatment

1HB ≤ 3HB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	4.255833333	8.888181818
Variance	0.276347101	2.231091775
Observations	24	22
Hypothesized Mean Difference	0	
df	26	
t Stat	-13.78481473	
P(T<=t) one-tail	9.14533E-14	
t Critical one-tail	1.705617901	
P(T<=t) two-tail	1.82907E-13	
t Critical two-tail	2.055529418	

2NL ≤ 4NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	6.137222222	15.42692308
Variance	0.366226349	14.67649415
Observations	36	26
Hypothesized Mean Difference	0	
df	26	
t Stat	-12.25458763	
P(T<=t) one-tail	1.31418E-12	
t Critical one-tail	1.705617901	
P(T<=t) two-tail	2.62836E-12	
t Critical two-tail	2.055529418	

2HL ≤ 4HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	7.2925	30.61857143
Variance	1.063925	5.057259341
Observations	20	14
Hypothesized Mean Difference	0	
df	17	
t Stat	-36.23401842	
P(T<=t) one-tail	7.72937E-18	
t Critical one-tail	1.739606716	
P(T<=t) two-tail	1.54587E-17	
t Critical two-tail	2.109815559	

Appendix A, Table 3: T-Tests Comparison Data

Comparison:Treatment

2NB ≤ 4NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.82175	9.908
Variance	0.356510823	0.992116296
Observations	80	55
Hypothesized Mean Difference	0	
df	81	
t Stat	-33.91220452	
P(T<=t) one-tail	6.27182E-50	
t Critical one-tail	1.663883913	
P(T<=t) two-tail	1.25436E-49	
t Critical two-tail	1.989686288	

2HB ≤ 4HB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	5.574583333	9.661
Variance	0.490747645	1.431156842
Observations	24	20
Hypothesized Mean Difference	0	
df	29	
t Stat	-13.47210233	
P(T<=t) one-tail	2.59199E-14	
t Critical one-tail	1.699126996	
P(T<=t) two-tail	5.18397E-14	
t Critical two-tail	2.045229611	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Moisture Content

1NL ≤ 2NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.008125	6.137222222
Variance	0.219860887	0.366226349
Observations	32	36
Hypothesized Mean Difference	0	
df	65	
t Stat	-16.30852709	
P(T<=t) one-tail	5.82542E-25	
t Critical one-tail	1.668635976	
P(T<=t) two-tail	1.16508E-24	
t Critical two-tail	1.997137887	

1HL ≤ 2HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	7.429	7.2925
Variance	8.414556842	1.063925
Observations	20	20
Hypothesized Mean Difference	0	
df	24	
t Stat	0.198279702	
P(T<=t) one-tail	0.422248105	
t Critical one-tail	1.710882067	
P(T<=t) two-tail	0.84449621	
t Critical two-tail	2.063898547	

1NB ≤ 2NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.411428571	4.82175
Variance	0.313773838	0.356510823
Observations	84	80
Hypothesized Mean Difference	0	
df	160	
t Stat	-4.533512763	
P(T<=t) one-tail	5.65557E-06	
t Critical one-tail	1.654432902	
P(T<=t) two-tail	1.13111E-05	
t Critical two-tail	1.974901524	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Moisture Content

1HB ≤ 2HB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.255833333	5.574583333
Variance	0.276347101	0.490747645
Observations	24	24
Hypothesized Mean Difference	0	
df	43	
t Stat	-7.376385226	
P(T<=t) one-tail	1.84193E-09	
t Critical one-tail	1.681070704	
P(T<=t) two-tail	3.68387E-09	
t Critical two-tail	2.016692173	

3NL ≤ 4NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	13.126	15.42692308
Variance	4.591204211	14.67649415
Observations	20	26
Hypothesized Mean Difference	0	
df	41	
t Stat	-2.582145456	
P(T<=t) one-tail	0.006744429	
t Critical one-tail	1.682878003	
P(T<=t) two-tail	0.013488859	
t Critical two-tail	2.019540948	

3HL ≤ 4HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	16.0645	30.61857143
Variance	8.628352368	5.057259341
Observations	20	14
Hypothesized Mean Difference	0	
df	32	
t Stat	-16.34721041	
P(T<=t) one-tail	2.1591E-17	
t Critical one-tail	1.693888703	
P(T<=t) two-tail	4.3182E-17	
t Critical two-tail	2.036933334	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Moisture Content

3NB ≤ 4NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	9.001176471	9.908
Variance	0.707058588	0.992116296
Observations	51	55
Hypothesized Mean Difference	0	
df	103	
t Stat	-5.077048274	
P(T<=t) one-tail	8.55217E-07	
t Critical one-tail	1.659782274	
P(T<=t) two-tail	1.71043E-06	
t Critical two-tail	1.98326409	

3HB ≤ 4HB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	8.888181818	9.661
Variance	2.231091775	1.431156842
Observations	22	20
Hypothesized Mean Difference	0	
df	39	
t Stat	-1.858191853	
P(T<=t) one-tail	0.035350995	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	0.070701991	
t Critical two-tail	2.022690901	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Age

1HB ≤ 1NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.255833333	4.411428571
Variance	0.276347101	0.313773838
Observations	24	84
Hypothesized Mean Difference	0	
df	39	
t Stat	-1.25997897	
P(T<=t) one-tail	0.10758228	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	0.215164561	
t Critical two-tail	2.022690901	

2HB ≤ 2NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	5.574583333	4.82175
Variance	0.490747645	0.356510823
Observations	24	80
Hypothesized Mean Difference	0	
df	34	
t Stat	4.77048472	
P(T<=t) one-tail	1.70075E-05	
t Critical one-tail	1.690924198	
P(T<=t) two-tail	3.40151E-05	
t Critical two-tail	2.032244498	

3HB ≤ 3NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	8.888181818	9.001176471
Variance	2.231091775	0.707058588
Observations	22	51
Hypothesized Mean Difference	0	
df	27	
t Stat	-0.332802257	
P(T<=t) one-tail	0.370926938	
t Critical one-tail	1.703288423	
P(T<=t) two-tail	0.741853875	
t Critical two-tail	2.051830493	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Age

4HB ≤ 4NB

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	9.661	9.908
Variance	1.431156842	0.992116296
Observations	20	55
Hypothesized Mean Difference	0	
df	29	
t Stat	-0.825186029	
P(T<=t) one-tail	0.208001289	
t Critical one-tail	1.699126996	
P(T<=t) two-tail	0.416002579	
t Critical two-tail	2.045229611	

1HL ≤ 1NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	7.429	4.008125
Variance	8.414556842	0.219860887
Observations	20	32
Hypothesized Mean Difference	0	
df	20	
t Stat	5.231414374	
P(T<=t) one-tail	2.02346E-05	
t Critical one-tail	1.724718218	
P(T<=t) two-tail	4.04693E-05	
t Critical two-tail	2.085963441	

2HL ≤ 2NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	7.2925	6.137222222
Variance	1.063925	0.366226349
Observations	20	36
Hypothesized Mean Difference	0	
df	26	
t Stat	4.589308929	
P(T<=t) one-tail	4.96941E-05	
t Critical one-tail	1.705617901	
P(T<=t) two-tail	9.93883E-05	
t Critical two-tail	2.055529418	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Age

3HL ≤ 3NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	16.0645	13.126
Variance	8.628352368	4.591204211
Observations	20	20
Hypothesized Mean Difference	0	
df	35	
t Stat	3.614367004	
P(T<=t) one-tail	0.000468529	
t Critical one-tail	1.68957244	
P(T<=t) two-tail	0.000937059	
t Critical two-tail	2.030107915	

4HL ≤ 4NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	30.61857143	15.42692308
Variance	5.057259341	14.67649415
Observations	14	26
Hypothesized Mean Difference	0	
df	38	
t Stat	15.78943663	
P(T<=t) one-tail	1.39527E-18	
t Critical one-tail	1.685954461	
P(T<=t) two-tail	2.79053E-18	
t Critical two-tail	2.024394147	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Wood Type

1HB ≤ 1HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.255833333	7.429
Variance	0.276347101	8.414556842
Observations	24	20
Hypothesized Mean Difference	0	
df	20	
t Stat	-4.82646597	
P(T<=t) one-tail	5.12678E-05	
t Critical one-tail	1.724718218	
P(T<=t) two-tail	0.000102536	
t Critical two-tail	2.085963441	

1NB ≤ 1NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	4.411428571	4.008125
Variance	0.313773838	0.219860887
Observations	84	32
Hypothesized Mean Difference	0	
df	67	
t Stat	3.916112135	
P(T<=t) one-tail	0.000106726	
t Critical one-tail	1.667916115	
P(T<=t) two-tail	0.000213451	
t Critical two-tail	1.996008331	

2HB ≤ 2HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	5.574583333	7.2925
Variance	0.490747645	1.063925
Observations	24	20
Hypothesized Mean Difference	0	
df	32	
t Stat	-6.330429934	
P(T<=t) one-tail	2.09227E-07	
t Critical one-tail	1.693888703	
P(T<=t) two-tail	4.18454E-07	
t Critical two-tail	2.036933334	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Wood Type

2NB ≤ 2NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	4.82175	6.137222222
Variance	0.356510823	0.366226349
Observations	80	36
Hypothesized Mean Difference	0	
df	67	
t Stat	-10.87600312	
P(T<=t) one-tail	9.56917E-17	
t Critical one-tail	1.667916115	
P(T<=t) two-tail	1.91383E-16	
t Critical two-tail	1.996008331	

3HB ≤ 3HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	8.888181818	16.0645
Variance	2.231091775	8.628352368
Observations	22	20
Hypothesized Mean Difference	0	
df	28	
t Stat	-9.831210445	
P(T<=t) one-tail	6.99815E-11	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	1.39963E-10	
t Critical two-tail	2.048407115	

3NB ≤ 3NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	9.001176471	13.126
Variance	0.707058588	4.591204211
Observations	51	20
Hypothesized Mean Difference	0	
df	21	
t Stat	-8.360333125	
P(T<=t) one-tail	2.01739E-08	
t Critical one-tail	1.720742871	
P(T<=t) two-tail	4.03477E-08	
t Critical two-tail	2.079613837	

Appendix A, Table 3: T-Tests Comparison Data

Comparison: Wood Type

4HB ≤ 4HL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	9.661	30.61857143
Variance	1.431156842	5.057259341
Observations	20	14
Hypothesized Mean Difference	0	
df	18	
t Stat	-31.85679047	
P(T<=t) one-tail	1.38604E-17	
t Critical one-tail	1.734063592	
P(T<=t) two-tail	2.77208E-17	
t Critical two-tail	2.100922037	

4NB ≤ 4NL

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	9.908	15.42692308
Variance	0.992116296	14.67649415
Observations	55	26
Hypothesized Mean Difference	0	
df	27	
t Stat	-7.231015373	
P(T<=t) one-tail	4.44954E-08	
t Critical one-tail	1.703288423	
P(T<=t) two-tail	8.89907E-08	
t Critical two-tail	2.051830493	

Appendix A, Table 4: Drying Data

	Weight Loss Through Drying						
	25-Jan	26-Jan	28-Jan	29-Jan	30-Jan	31-Jan	1-Feb
Temp (ºC)	60	60	60	70	85	95	95
Piece							
HWL1	1045.39	967.02	955.21	950.07	945.3	941.3	942.61
HWL2	1176.57	1089.75	1075.62	1072.22	1063.09	1061.55	1060.53
HWL3	1024.78	947.12	935.11	928.85	926.72	922.83	923.89
HWL4	530.24	484.09	482.57	479.84	477.62	476.96	477.46
HWB1	123.23	113.04	112.24	112.11	111.52	111.26	111.43
HWB2	91.8	82.79	82.67	82.63	82.29	82.1	82.24
HWB3	99.52	89.46	89.39	89.43	89	88.79	88.9
HWB4	108.07	96.94	96.83	96.91	96.38	96.13	96.26
HWB5	125.54	111.91	111.75	111.82	110.99	110.66	110.79
HWB6	133.88	118.22	118.07	117.94	117.41	117.07	117.28
HWB7	139.85	122.18	122.09	122.01	121.46	121.09	121.3
HWB8	157.44	136.04	135.85	135.79	135.12	134.67	134.81
HWB9	161.33	138.83	139.15	138.61	137.71	137.21	137.43
HWB10	167.49	142.86	143.01	142.7	141.96	141.37	141.67
HWB11	172.99	147.85	148.38	147.86	146.86	146.35	146.7
HWB12A	54.66	46.28	46.44	46.31	46.04	45.94	46.12
HWB12B	86.27	74.03	74.12	74	73.56	73.37	73.52
NWL1.1	465.49	412.61	409.81	408.29	407.7	406.45	406.55
NWL1.2	463.73	379.03	369.01	363.72	362.93	361.76	362.06
NWL1.3	573.97	506.01	496.17	492.84	490.88	490.63	491.21
NWL1.4	604.28	496.77	486.91	485.39	481.65	481.2	481.44
NWL3.1	483.4	406.75	397.36	394.35	392.09	390.81	391.53
NWL3.2	473.78	384.35	380.39	377.15	375.71	374.34	374.82
NWL3.3	583	494.62	475.74	473.47	471.4	469.46	470.07
NWL3.4	576.15	470.17	460.77	458.79	456.77	455.23	455.75
NWL4.1	482.16	395.73	387.23	384.91	383.24	382.23	382.2
NWL4.2	459.34	373.03	363.72	362.19	360.53	359.15	359.5
NWL4.3	540.62	434.6	429.3	426.77	425.22	423.46	422.92
NWL4.4	600.9	493.61	486.8	484.27	481.29	479.86	479.4
NWL5.1	424.01	345.01	345.01	342.66	340.75	339.52	340.17
NWL5.2	367.28	295.74	291.39	290.24	288.82	288.13	288.21
NWL5.3	526.22	459.15	457.16	454.64	452.66	450.84	451.45
NWL5.4	570.35	421.87	416.79	414.56	411.93	411.37	411.85
NWB1.1	43.98	41.17	40.92	40.79	40.63	40.53	40.57
NWB1.2	44.11	41.17	40.93	40.81	40.67	40.54	40.57
NWB1.3	47.11	43.96	43.67	43.57	43.41	43.25	43.29
NWB1.4	54.64	51.92	50.94	50.69	50.56	50.37	50.37

Appendix A, Table 4: Drying Data

	2-Feb	3-Feb	4-Feb	6-Feb	7-Feb	8-Feb	9-Feb
Temp (ºC)	100	60	115	110	110	110	110
Piece							
HWL1	939.76	941.9	934.89	934.58	934.08	933.29	933.6
HWL2	1057.9	1059.62	1055.6	1055.67	1054.69	1054.52	1053.99
HWL3	921.03	922.54	916.26	916.13	916.68	915.1	915.31
HWL4	476.54	478.65	476	475.84	475.41	474.76	474.79
HWB1	111.34	111.59	111.21	111.07	110.95	110.76	110.66
HWB2	82.15	82.33	81.02	81.98	81.83	81.71	81.63
HWB3	88.78	89.04	88.69	88.64	88.42	88.31	88.24
HWB4	96.08	96.34	95.97	95.87	95.64	95.53	95.39
HWB5	110.61	110.94	110.47	110.28	110.09	109.97	109.59
HWB6	117.09	117.38	116.94	116.73	116.59	116.51	116.28
HWB7	121.13	121.43	120.95	120.8	120.59	120.53	120.32
HWB8	134.6	135	134.55	134.08	133.79	133.7	133.49
HWB9	137.17	137.68	137.18	136.78	136.74	136.54	136.41
HWB10	141.35	141.92	141.37	140.99	141	140.86	140.73
HWB11	146.28	146.88	146.28	145.83	145.63	145.36	145.22
HWB12A	45.96	46.13	45.97	45.86	45.77	45.71	45.69
HWB12B	73.36	73.6	73.34	73.25	73.11	72.97	72.94
NWL1.1	404.78	406.46	405.24	405.08	404.57	404.36	404.31
NWL1.2	360.17	361.63	360.53	360.56	360.09	359.9	359.72
NWL1.3	490.01	491.23	490.33	490.19	489.55	489.35	489.07
NWL1.4	478.81	480.4	479.46	479.09	478.83	478.84	478.53
NWL3.1	390.72	391.51	389.43	389.57	388.73	387.94	388.2
NWL3.2	373.7	374.77	372.63	372.94	371.47	371.32	371.42
NWL3.3	468.93	469.8	467.97	467.58	467.09	465.86	466.12
NWL3.4	455.25	456.42	453.79	454.05	452.31	451.27	451.13
NWL4.1	381.94	382.83	381.95	381.62	381.18	381.08	380.88
NWL4.2	358.58	359.75	358.29	358	357.77	357.32	357
NWL4.3	422.67	423.8	422.17	421.96	421.39	421.28	420.75
NWL4.4	479.08	480.23	478.88	478.72	477.94	477.28	477.18
NWL5.1	339.38	340.71	339.78	338.92	338.69	338.69	338.15
NWL5.2	287.5	288.55	287.79	287.22	287.02	286.95	286.57
NWL5.3	450.16	452.03	450.53	450.63	449.88	449.82	449.3
NWL5.4	410.81	412.55	411.38	410.98	410.69	410.62	409.83
NWB1.1	40.5	40.6	40.48	40.5	40.46	40.42	40.43
NWB1.2	40.51	40.6	40.49	40.5	40.5	40.44	40.44
NWB1.3	43.23	43.34	43.22	43.22	43.18	43.15	43.15
NWB1.4	50.3	50.43	50.28	50.27	50.26	50.22	50.22

Appendix A, Table 4: Drying Data

	Percentage Change in Weight						
	25-Jan	26-Jan	28-Jan	29-Jan	30-Jan	31-Jan	1-Feb
Temp (ºC)							
Piece							
HWL1	0%	7%	9%	9%	10%	10%	10%
HWL2	0%	7%	9%	9%	10%	10%	10%
HWL3	0%	8%	9%	9%	10%	10%	10%
HWL4	0%	9%	9%	10%	10%	10%	10%
HWB1	0%	8%	9%	9%	10%	10%	10%
HWB2	0%	10%	10%	10%	10%	11%	10%
HWB3	0%	10%	10%	10%	11%	11%	11%
HWB4	0%	10%	10%	10%	11%	11%	11%
HWB5	0%	11%	11%	11%	12%	12%	12%
HWB6	0%	12%	12%	12%	12%	13%	12%
HWB7	0%	13%	13%	13%	13%	13%	13%
HWB8	0%	14%	14%	14%	14%	14%	14%
HWB9	0%	14%	14%	14%	15%	15%	15%
HWB10	0%	15%	15%	15%	15%	16%	15%
HWB11	0%	15%	14%	15%	15%	15%	15%
HWB12A	0%	15%	15%	15%	16%	16%	16%
HWB12B	0%	14%	14%	14%	15%	15%	15%
NWL1.1	0%	11%	12%	12%	12%	13%	13%
NWL1.2	0%	18%	20%	22%	22%	22%	22%
NWL1.3	0%	12%	14%	14%	14%	15%	14%
NWL1.4	0%	18%	19%	20%	20%	20%	20%
NWL3.1	0%	16%	18%	18%	19%	19%	19%
NWL3.2	0%	19%	20%	20%	21%	21%	21%
NWL3.3	0%	15%	18%	19%	19%	19%	19%
NWL3.4	0%	18%	20%	20%	21%	21%	21%
NWL4.1	0%	18%	20%	20%	21%	21%	21%
NWL4.2	0%	19%	21%	21%	22%	22%	22%
NWL4.3	0%	20%	21%	21%	21%	22%	22%
NWL4.4	0%	18%	19%	19%	20%	20%	20%
NWL5.1	0%	19%	19%	19%	20%	20%	20%
NWL5.2	0%	19%	21%	21%	21%	22%	22%
NWL5.3	0%	13%	13%	14%	14%	14%	14%
NWL5.4	0%	26%	27%	27%	28%	28%	28%
NWB1.1	0%	6%	7%	7%	8%	8%	8%
NWB1.2	0%	7%	7%	7%	8%	8%	8%
NWB1.3	0%	7%	7%	8%	8%	8%	8%
NWB1.4	0%	5%	7%	7%	7%	8%	8%

Appendix A, Table 4: Drying Data

	2-Feb	3-Feb	4-Feb	6-Feb	7-Feb	8-Feb	9-Feb
Temp (ºC)							
Piece							
HWL1	10%	10%	11%	11%	11%	11%	11%
HWL2	10%	10%	10%	10%	10%	10%	10%
HWL3	10%	10%	11%	11%	11%	11%	11%
HWL4	10%	10%	10%	10%	10%	10%	10%
HWB1	10%	9%	10%	10%	10%	10%	10%
HWB2	11%	10%	12%	11%	11%	11%	11%
HWB3	11%	11%	11%	11%	11%	11%	11%
HWB4	11%	11%	11%	11%	12%	12%	12%
HWB5	12%	12%	12%	12%	12%	12%	13%
HWB6	13%	12%	13%	13%	13%	13%	13%
HWB7	13%	13%	14%	14%	14%	14%	14%
HWB8	15%	14%	15%	15%	15%	15%	15%
HWB9	15%	15%	15%	15%	15%	15%	15%
HWB10	16%	15%	16%	16%	16%	16%	16%
HWB11	15%	15%	15%	16%	16%	16%	16%
HWB12A	16%	16%	16%	16%	16%	16%	16%
HWB12B	15%	15%	15%	15%	15%	15%	15%
NWL1.1	13%	13%	13%	13%	13%	13%	13%
NWL1.2	22%	22%	22%	22%	22%	22%	22%
NWL1.3	15%	14%	15%	15%	15%	15%	15%
NWL1.4	21%	21%	21%	21%	21%	21%	21%
NWL3.1	19%	19%	19%	19%	20%	20%	20%
NWL3.2	21%	21%	21%	21%	22%	22%	22%
NWL3.3	20%	19%	20%	20%	20%	20%	20%
NWL3.4	21%	21%	21%	21%	21%	22%	22%
NWL4.1	21%	21%	21%	21%	21%	21%	21%
NWL4.2	22%	22%	22%	22%	22%	22%	22%
NWL4.3	22%	22%	22%	22%	22%	22%	22%
NWL4.4	20%	20%	20%	20%	20%	21%	21%
NWL5.1	20%	20%	20%	20%	20%	20%	20%
NWL5.2	22%	21%	22%	22%	22%	22%	22%
NWL5.3	14%	14%	14%	14%	15%	15%	15%
NWL5.4	28%	28%	28%	28%	28%	28%	28%
NWB1.1	8%	8%	8%	8%	8%	8%	8%
NWB1.2	8%	8%	8%	8%	8%	8%	8%
NWB1.3	8%	8%	8%	8%	8%	8%	8%
NWB1.4	8%	8%	8%	8%	8%	8%	8%

Appendix A, Table 4: Drying Data

	Weight Loss Through Drying						
	25-Jan	26-Jan	28-Jan	29-Jan	30-Jan	31-Jan	1-Feb
NWB2.1	62.23	58.47	58	57.94	57.79	57.5	57.52
NWB2.2	51.65	48.2	47.88	47.88	47.75	47.52	47.55
NWB2.3	53.91	50.3	49.95	49.98	49.81	49.6	49.64
NWB2.4	53.61	50.1	49.75	49.83	49.62	49.44	49.49
NWB3.1	58.78	54.55	54.25	54.4	54.16	53.95	54.07
NWB3.2	56.52	52.24	52.01	52.12	51.85	51.67	51.75
NWB3.3	56.85	52.41	52.23	52.33	52.13	51.92	51.98
NWB3.4	60.12	55.51	55.29	55.43	55.21	54.97	55.02
NWB4.1	43.93	41.56	40.94	40.86	40.65	40.54	40.62
NWB4.2	48.01	45.4	44.69	44.61	44.36	44.19	44.24
NWB4.3	43.87	41.55	40.94	40.92	40.75	40.63	40.69
NWB4.4	47.45	44.98	44.25	44.24	44.04	43.9	43.96
NWB5.1	64.47	60.84	60.23	60.1	59.94	59.73	59.78
NWB5.2	60.19	56.89	56.29	56.19	56.01	55.88	55.92
NWB5.3	78.72	74.72	73.86	73.72	73.43	73.19	73.23
NWB5.4	62.85	59.36	58.91	58.86	58.66	58.47	58.54
NWB6.1	53.76	51.01	49.87	49.76	49.55	49.32	49.36
NWB6.2	50.26	48.15	46.33	46.23	46.08	45.87	45.91
NWB6.3	51.91	48.65	47.96	47.71	47.52	47.32	47.35
NWB6.4	59.44	56.03	55	54.7	54.45	54.21	54.21
NWB6.5	59.24	55.26	54.72	54.53	54.32	54.11	54.11
NWB6.6	63.51	59.44	58.92	58.75	58.55	58.32	58.38
NWB6.7	52.21	49.69	48.72	48.54	48.31	48.13	48.16
NWB6.8	50.31	47.36	46.67	46.55	46.36	46.2	46.24
NWB6.9	50.55	47.55	46.75	46.65	46.46	46.3	46.32
NWB6.10	52.53	49.53	48.56	48.46	48.23	48.07	48.11
NWB6.11	50.42	47.28	46.59	46.53	46.27	46.14	46.17
NWB6.12	61.3	57.52	57.07	56.99	56.69	56.52	56.55
NWB7.1	52.62	49.57	48.84	48.84	48.66	48.5	48.62
NWB7.2	51.69	48.16	47.8	47.8	47.66	47.47	47.6
NWB7.3	51.27	47.91	47.26	47.25	47.23	46.94	47.08
NWB7.4	50.98	47.61	46.96	46.92	46.87	46.6	46.71
NWB7.5	50.58	46.91	46.59	46.54	46.45	46.22	46.35
NWB7.6	49.96	46.43	46.07	46.07	45.99	45.76	45.91

Appendix A, Table 4: Drying Data

	2-Feb	3-Feb	4-Feb	6-Feb	7-Feb	8-Feb	9-Feb
NWB2.1	57.44	57.57	57.4	57.49	57.38	57.38	57.28
NWB2.2	47.49	47.62	47.47	47.55	47.44	47.42	47.35
NWB2.3	49.55	49.71	49.54	49.61	49.51	49.52	49.43
NWB2.4	49.4	49.55	49.39	49.44	49.36	49.34	49.27
NWB3.1	53.97	54.21	54.02	54.04	53.89	53.86	53.85
NWB3.2	51.66	51.95	51.69	51.72	51.58	51.56	51.54
NWB3.3	51.92	52.18	51.94	51.95	51.84	51.81	51.77
NWB3.4	54.97	55.22	54.97	54.98	54.87	54.85	54.8
NWB4.1	40.52	40.66	40.48	40.53	40.47	40.46	40.38
NWB4.2	45.15	44.23	44.09	44.15	44.09	44.06	44
NWB4.3	40.59	40.74	40.54	40.6	40.54	40.51	40.48
NWB4.4	43.84	43.98	43.81	43.86	43.8	43.75	43.71
NWB5.1	59.76	59.91	59.66	59.66	59.58	59.54	59.53
NWB5.2	55.88	56.03	55.81	55.82	55.75	55.72	55.7
NWB5.3	73.14	73.31	73.02	73.03	72.94	72.92	72.87
NWB5.4	58.49	58.68	58.37	58.41	58.35	58.34	58.28
NWB6.1	49.31	49.43	49.26	49.2	49.17	49.1	49.12
NWB6.2	45.85	45.98	45.83	45.77	45.73	45.71	45.71
NWB6.3	47.29	47.41	47.26	47.2	47.16	47.13	47.13
NWB6.4	54.09	54.2	54.05	54	53.96	53.94	53.92
NWB6.5	53.96	54.07	53.91	53.86	53.84	53.82	53.79
NWB6.6	58.17	58.33	58.14	58.06	58.05	58.04	57.98
NWB6.7	48.12	48.24	48.06	47.98	47.94	47.92	47.92
NWB6.8	46.19	46.3	46.14	46.1	46.05	46.03	46.03
NWB6.9	47.27	46.4	46.24	46.23	46.17	46.15	46.13
NWB6.10	48.01	48.13	48	47.97	47.93	47.91	47.88
NWB6.11	46.06	46.19	46.08	46.02	45.98	45.97	45.95
NWB6.12	56.52	56.53	56.42	56.34	56.29	56.28	56.27
NWB7.1	48.55	48.66	48.44	48.51	48.43	48.4	48.39
NWB7.2	47.52	47.64	47.44	47.5	47.41	47.38	47.38
NWB7.3	47	47.11	46.91	46.98	46.86	46.86	46.85
NWB7.4	46.67	46.77	46.58	46.63	46.54	46.52	46.53
NWB7.5	46.31	46.4	46.22	46.26	46.18	46.17	46.17
NWB7.6	45.85	45.95	45.75	45.78	45.72	45.7	45.7

Appendix A, Table 4: Drying Data

	Percentage Change in Weight						
	25-Jan	26-Jan	28-Jan	29-Jan	30-Jan	31-Jan	1-Feb
NWB2.1	0%	6%	7%	7%	7%	8%	8%
NWB2.2	0%	7%	7%	7%	8%	8%	8%
NWB2.3	0%	7%	7%	7%	8%	8%	8%
NWB2.4	0%	7%	7%	7%	7%	8%	8%
NWB3.1	0%	7%	8%	7%	8%	8%	8%
NWB3.2	0%	8%	8%	8%	8%	9%	8%
NWB3.3	0%	8%	8%	8%	8%	9%	9%
NWB3.4	0%	8%	8%	8%	8%	9%	8%
NWB4.1	0%	5%	7%	7%	7%	8%	8%
NWB4.2	0%	5%	7%	7%	8%	8%	8%
NWB4.3	0%	5%	7%	7%	7%	7%	7%
NWB4.4	0%	5%	7%	7%	7%	7%	7%
NWB5.1	0%	6%	7%	7%	7%	7%	7%
NWB5.2	0%	5%	6%	7%	7%	7%	7%
NWB5.3	0%	5%	6%	6%	7%	7%	7%
NWB5.4	0%	6%	6%	6%	7%	7%	7%
NWB6.1	0%	5%	7%	7%	8%	8%	8%
NWB6.2	0%	4%	8%	8%	8%	9%	9%
NWB6.3	0%	6%	8%	8%	8%	9%	9%
NWB6.4	0%	6%	7%	8%	8%	9%	9%
NWB6.5	0%	7%	8%	8%	8%	9%	9%
NWB6.6	0%	6%	7%	7%	8%	8%	8%
NWB6.7	0%	5%	7%	7%	7%	8%	8%
NWB6.8	0%	6%	7%	7%	8%	8%	8%
NWB6.9	0%	6%	8%	8%	8%	8%	8%
NWB6.10	0%	6%	8%	8%	8%	8%	8%
NWB6.11	0%	6%	8%	8%	8%	8%	8%
NWB6.12	0%	6%	7%	7%	8%	8%	8%
NWB7.1	0%	6%	7%	7%	8%	8%	8%
NWB7.2	0%	7%	8%	8%	8%	8%	8%
NWB7.3	0%	7%	8%	8%	8%	8%	8%
NWB7.4	0%	7%	8%	8%	8%	9%	8%
NWB7.5	0%	7%	8%	8%	8%	9%	8%
NWB7.6	0%	7%	8%	8%	8%	8%	8%

Appendix A, Table 4: Drying Data

	2-Feb	3-Feb	4-Feb	6-Feb	7-Feb	8-Feb	9-Feb
NWB2.1	8%	7%	8%	8%	8%	8%	8%
NWB2.2	8%	8%	8%	8%	8%	8%	8%
NWB2.3	8%	8%	8%	8%	8%	8%	8%
NWB2.4	8%	8%	8%	8%	8%	8%	8%
NWB3.1	8%	8%	8%	8%	8%	8%	8%
NWB3.2	9%	8%	9%	8%	9%	9%	9%
NWB3.3	9%	8%	9%	9%	9%	9%	9%
NWB3.4	9%	8%	9%	9%	9%	9%	9%
NWB4.1	8%	7%	8%	8%	8%	8%	8%
NWB4.2	6%	8%	8%	8%	8%	8%	8%
NWB4.3	7%	7%	8%	7%	8%	8%	8%
NWB4.4	8%	7%	8%	8%	8%	8%	8%
NWB5.1	7%	7%	7%	7%	8%	8%	8%
NWB5.2	7%	7%	7%	7%	7%	7%	7%
NWB5.3	7%	7%	7%	7%	7%	7%	7%
NWB5.4	7%	7%	7%	7%	7%	7%	7%
NWB6.1	8%	8%	8%	8%	9%	9%	9%
NWB6.2	9%	9%	9%	9%	9%	9%	9%
NWB6.3	9%	9%	9%	9%	9%	9%	9%
NWB6.4	9%	9%	9%	9%	9%	9%	9%
NWB6.5	9%	9%	9%	9%	9%	9%	9%
NWB6.6	8%	8%	8%	9%	9%	9%	9%
NWB6.7	8%	8%	8%	8%	8%	8%	8%
NWB6.8	8%	8%	8%	8%	8%	9%	9%
NWB6.9	6%	8%	9%	9%	9%	9%	9%
NWB6.10	9%	8%	9%	9%	9%	9%	9%
NWB6.11	9%	8%	9%	9%	9%	9%	9%
NWB6.12	8%	8%	8%	8%	8%	8%	8%
NWB7.1	8%	8%	8%	8%	8%	8%	8%
NWB7.2	8%	8%	8%	8%	8%	8%	8%
NWB7.3	8%	8%	9%	8%	9%	9%	9%
NWB7.4	8%	8%	9%	9%	9%	9%	9%
NWB7.5	8%	8%	9%	9%	9%	9%	9%
NWB7.6	8%	8%	8%	8%	8%	9%	9%

Appendix A, Table 5: Wetting Data

Piece	Target Weight	Weight (g) at 2/11/2008 12PM	%Water Needed	Weight (g) at 2/12 9PM	%Water Needed	Weight (g) at 2/12 12 PM	%Water Needed	Weight (g) at 2/13 9PM	%Water Needed
HWL1	1120.32	1322.28	-18%			1199.13	-7%		
HWB1	132.79	167.59	-26%	157.79	-19%	133.03	0%		
HWB5	131.51	166.01	-26%	159.36	-21%	137.97	-5%	133.46	-1%
HWB9	163.69	206.38	-26%	193.59	-18%	167.29	-2%	162.95	0%
NWL1.1	485.17	559.85	-15%	536.49	-11%	501.73	-3%	493.97	-2%
NWL3.1	465.84	538.77	-16%	516.91	-11%	487.22	-5%	478.18	-3%
NWL4.1	457.06	546.16	-19%		100%	486.46	-6%	476.07	-4%
NWL5.1	405.78	502.05	-24%	477.08	-18%	441.26	-9%	432	-6%
NWB1.1	48.52	49.15	-1%						
NWB2.1	68.74	69.89	-2%	68.96	0%				
NWB3.1	64.62	67.79	-5%	64.57	0%				
NWB4.1	48.46	49.08	-1%						
NWB5.1	71.44	72	-1%						
NWB6.1	58.94	59.11	0%						
NWB6.2	54.85	55.35	-1%						
NWB6.3	56.56	56.48	0%						
NWB7.1	58.07	61.4	-6%	58.86	-1%				
HWL2	1264.79	1481.39	-17%	1448.50	-15%	1358.09	-7%	1326	-5%
HWB2	97.96	124.4	-27%	119.27	-22%	102.43	-5%	99.41	-1%
HWB6	139.54	179.29	-28%	172.90	-24%	150.73	-8%	146.2	-5%
HWB10	168.88	222.7	-32%	214.10	-27%	181.74	-8%	174.44	-3%
NWL1.2	431.66	520.31	-21%	497.11	-15%	464.79	-8%	454.92	-5%
NWL3.2	445.70	525.23	-18%	501.98	-13%	472.09	-6%	463.28	-4%
NWL4.2	428.40	519.54	-21%	502.81	-17%	464	-8%	452.94	-6%
NWL5.2	343.88	448.17	-30%	429.28	-25%	399.98	-16%	389.11	-13%
NWB1.2	48.53	48.77	0%		100%				
NWB2.2	56.82	58.13	-2%	56.97	0%				
NWB3.2	61.85	63.21	-2%	62.64	-1%				
NWB4.2	52.80	52.96	0%		100%				
NWB5.2	66.84	67.05	0%		100%				
NWB6.4	64.70	63.33	2%	65.01	0%				
NWB6.5	64.55	63.82	1%	65.46	-1%				
NWB6.6	69.58	66.74	4%	69.57	0%				
NWB7.2	56.86	59.96	-5%	57.14	0%				

Appendix A, Table 5: Wetting Data

Piece	Weight (g) at 2/14/2008 12PM	%Water Needed	Weight (g) at 2/14 9PM	%Water Needed	Weight (g) at 2/15 at 12PM	%Water Needed	Weight (g) at 2/16 at 12PM	%Water Needed	Weight (g) at 2/17 at 12PM	%Water Needed
HWL1										
HWB1										
HWB5										
HWB9										
NWL1.1	479.03	1%								
NWL3.1	463.78	0%								
NWL4.1	459.07	0%								
NWL5.1	415.49	-2%	402.85	1%						
NWB1.1										
NWB2.1										
NWB3.1										
NWB4.1										
NWB5.1										
NWB6.1										
NWB6.2										
NWB6.3										
NWB7.1										
HWL2	1263.33	0%								
HWB2										
HWB6	140.01	0%								
HWB10	181.65	-8%	168.9	0%						
NWL1.2	436.56	-1%								
NWL3.2	448.92	-1%								
NWL4.2	434.97	-2%								
NWL5.2	369.91	-8%	348.97	-1%						
NWB1.2										
NWB2.2										
NWB3.2										
NWB4.2										
NWB5.2										
NWB6.4										
NWB6.5										
NWB6.6										
NWB7.2										

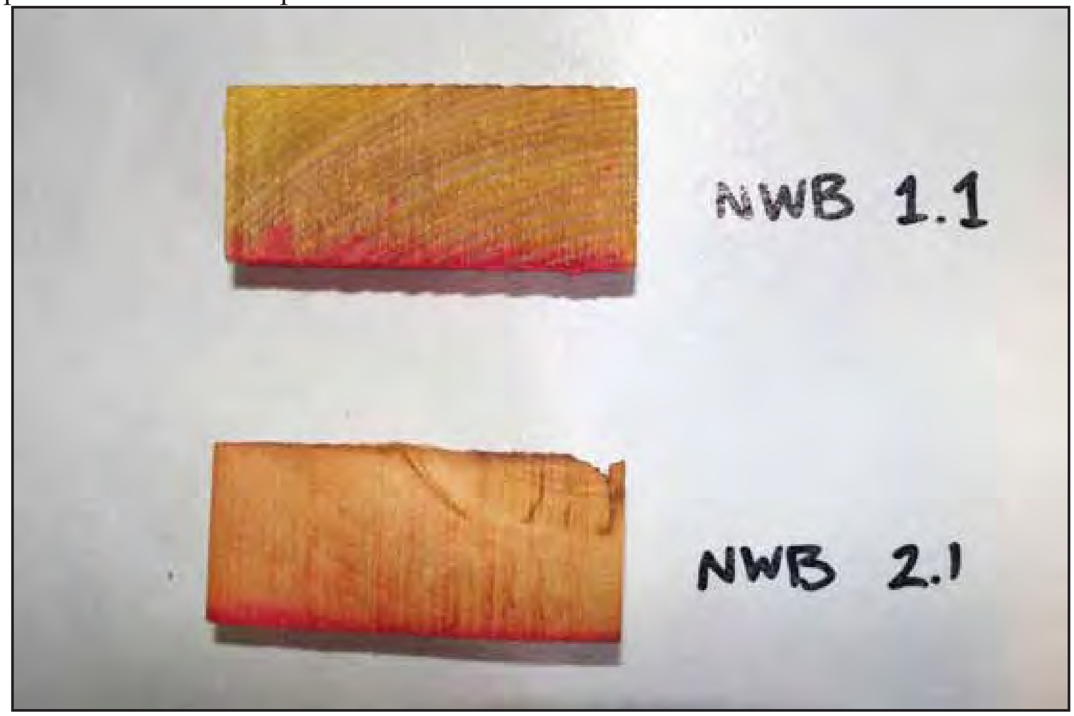
Appendix A, Table 5: Wetting Data

Piece	Target Weight	Weight (g) at 2/11/2008 12PM	%Water Needed	Weight (g) at 2/12 9PM	%Water Needed	Weight (g) at 2/12 12 PM	%Water Needed	Weight (g) at 2/13 9PM	%Water Needed
HWL3	1281.43	1287.1	0%	1277.74	0%				
HWB3	123.54	131.81	-7%	126.27	-2%				
HWB7	168.45	183.97	-9%	175.48	-4%	167.81	0%		
HWB11	203.31	222.42	-9%	207.20	-2%				
NWL1.3	684.70	671.68	2%	692.28	-1%				
NWL3.3	652.57	650.29	0%						
NWL4.3	589.05	610.65	-4%	594.95	-1%				
NWL5.3	629.02	639.42	-2%	620.12	1%				
NWB1.3	60.41	53.65	11%	55.29	8%	57.71	4%	58.64	3%
NWB2.3	69.20	63.21	9%	65.18	6%	68.03	2%	69.34	0%
NWB3.3	72.48	67.42	7%	70.10	3%	72.73	0%		
NWB4.3	56.67	52.07	8%	53.19	6%	54.99	3%	55.73	2%
NWB5.3	100.78	88.79	12%	92.24	8%	94.42	6%	96.45	4%
NWB6.7	67.09	56.78	15%	58.52	13%	60.66	10%	61.61	8%
NWB6.8	64.44	55.57	14%	57.19	11%	59.53	8%	60.5	6%
NWB6.9	64.58	55.91	13%	57.82	10%	59.88	7%	61.07	5%
NWB7.3	65.59	60.37	8%	62.46	5%	64.54	2%	65.46	0%
HWL4	664.71	716.14	-8%	691.31	-4%	649.46	2%	647.48	3%
HWB4	133.55	143.81	-8%	139.44	-4%	132.75	1%		
HWB8	186.89	204.26	-9%	194.57	-4%	186.02	0%		
HWB12A	63.97	76.88	-20%	71.43	-12%	66.07	-3%	64.21	0%
HWB12B	102.12	125.05	-22%	118.63	-16%	106.59	-4%	101.81	0%
NWL1.4	669.94	638.8	5%	659.87	2%	699.08	-4%	675.89	-1%
NWL3.4	631.58	611.83	3%	629.18	0%				
NWL4.4	668.05	668.19	0%						
NWL5.4	573.76	592.12	-3%	575.61	0%				
NWB1.4	70.31	60.39	14%	62.37	11%	64.99	8%	66.16	6%
NWB2.4	68.98	63.24	8%	65.02	6%	67.62	2%	68.9	0%
NWB3.4	76.72	71.17	7%	73.43	4%	76.58	0%		
NWB4.4	61.19	54.08	12%	55.34	10%	57.08	7%	57.91	5%
NWB5.4	81.59	76.02	7%	77.52	5%	80.25	2%	81.66	0%
NWB6.10	67.03	58.08	13%	59.73	11%	62.04	7%	63.19	6%
NWB6.11	64.33	56.27	13%	57.67	10%	59.9	7%	60.99	5%
NWB6.12	78.78	67.84	14%	69.55	12%	71.94	9%	73.25	7%
NWB7.4	65.14	60.66	7%	62.23	4%	64.54	1%		

Appendix A, Table 5: Wetting Data

Piece	Weight (g) at 2/14/2008 12PM	%Water Needed	Weight (g) at 2/14 9PM	%Water Needed	Weight (g) at 2/15 at 12PM	%Water Needed	Weight (g) at 2/16 at 12PM	%Water Needed	Weight (g) at 2/17 at 12PM	%Water Needed
HWL3										
HWB3										
HWB7										
HWB11										
NWL1.3										
NWL3.3										
NWL4.3										
NWL5.3										
NWB1.3	60.15	0%								
NWB2.3										
NWB3.3										
NWB4.3	57.21	-1%								
NWB5.3	99.59	1%								
NWB6.7	63.08	6%	64.65	4%	66.08	2%	67.44	-1%		
NWB6.8	62	4%	63.4	2%	65.08	-1%				
NWB6.9	62.3	4%	63.95	1%						
NWB7.3										
HWL4	640.61	4%	691.48	-4%	578.79	13%	694.63	-5%	673.34	-1%
HWB4										
HWB8										
HWB12A										
HWB12B										
NWL1.4										
NWL3.4										
NWL4.4										
NWL5.4										
NWB1.4	67.71	4%	69.67	1%						
NWB2.4										
NWB3.4										
NWB4.4	59.3	3%	60.25	2%	61.61	-1%				
NWB5.4										
NWB6.10	64.81	3%	66.3	1%						
NWB6.11	62.52	3%	63.83	1%						
NWB6.12	74.99	5%	76.55	3%	78.16	1%				
NWB7.4										

Appendix B: Select Sample Photos



NWB1.1 & NWB2.1, Week 1 Testing, Sample Set 1, 20%MC and DOT in Water.
Approximate dimensions: 26mm x 56mm

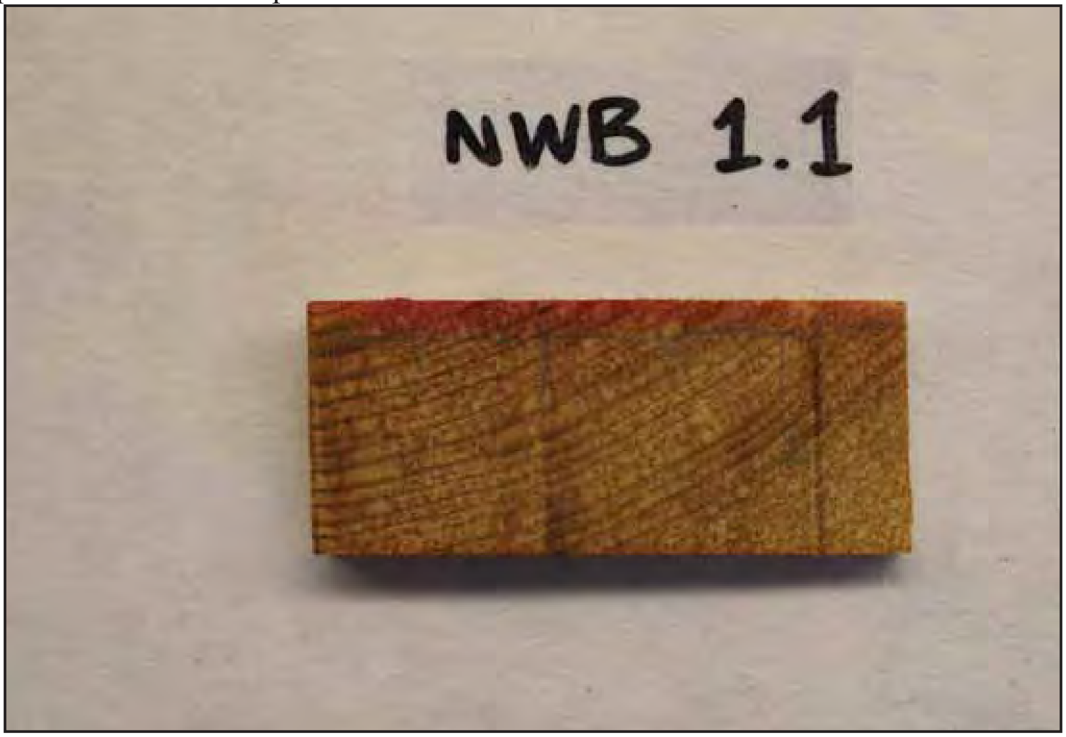
NWL1.1, Week 1 Testing, Sample Set 1, 20%MC and DOT in Water.
Approximate radial dimensions: 114mm & 98mm

Appendix B: Select Sample Photos

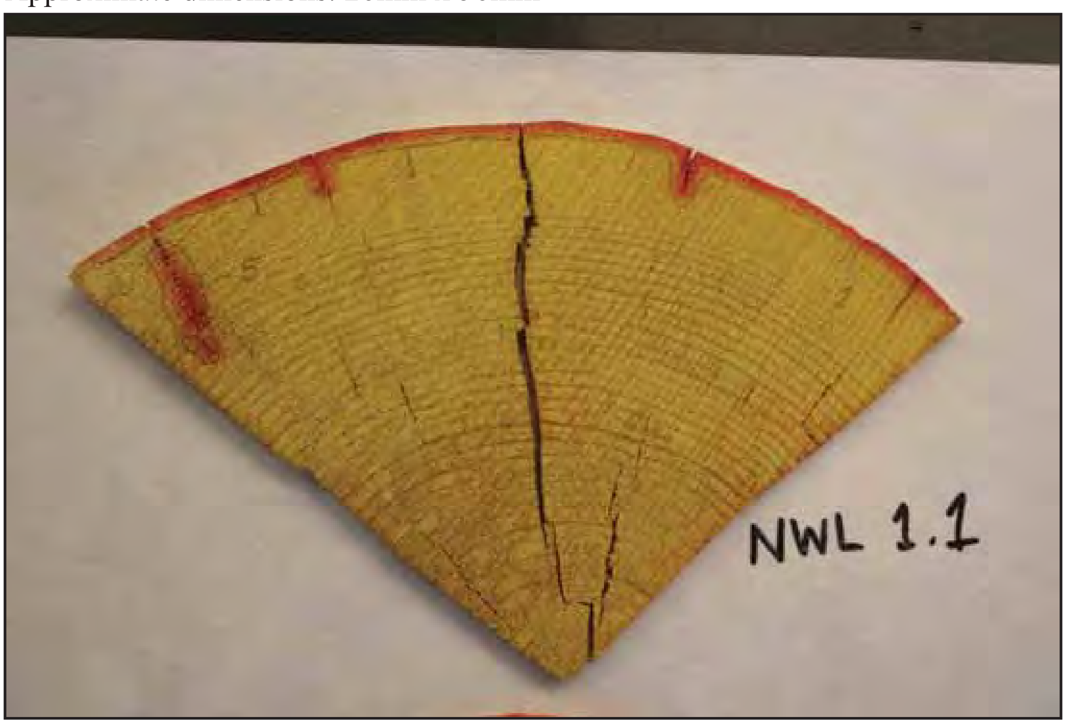
HWB1, Week 1 Testing, Sample Set 1, 20%MC and DOT in Water.
Approximate dimensions: 26mm x 136mm

HWL1, Week 1 Testing, Sample Set 1, 20%MC and DOT in Water. Approximate width: 170mm

Appendix B: Select Sample Photos

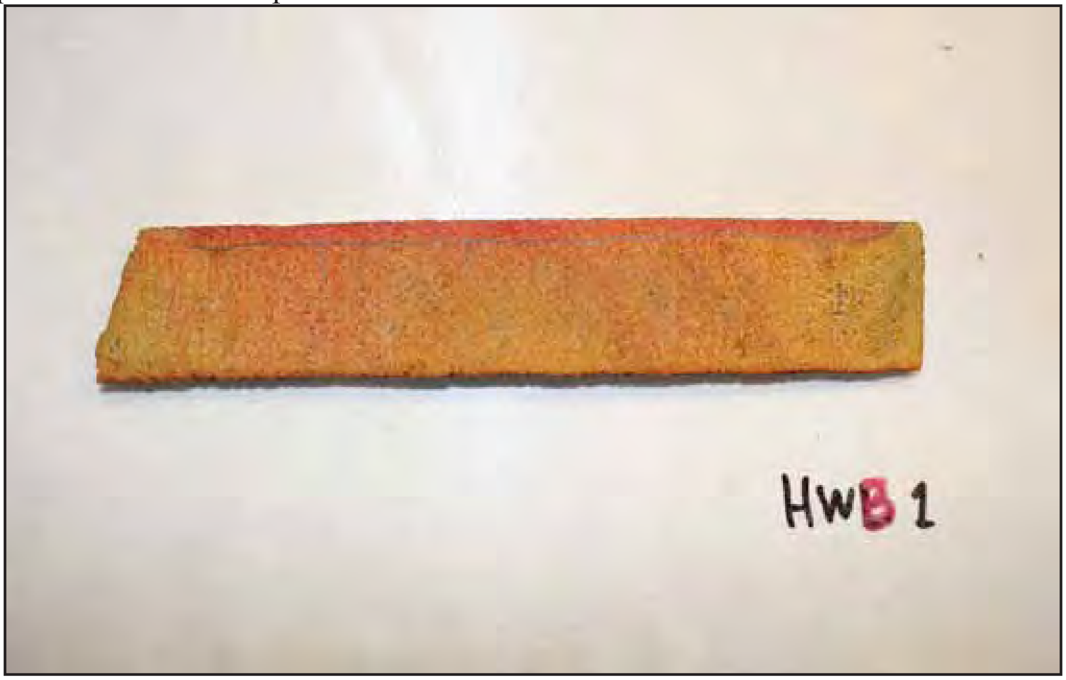


NWB1.1, Week 3 Testing, Sample Set 1, 20%MC and DOT in Water.
Approximate dimensions: 26mm x 56mm

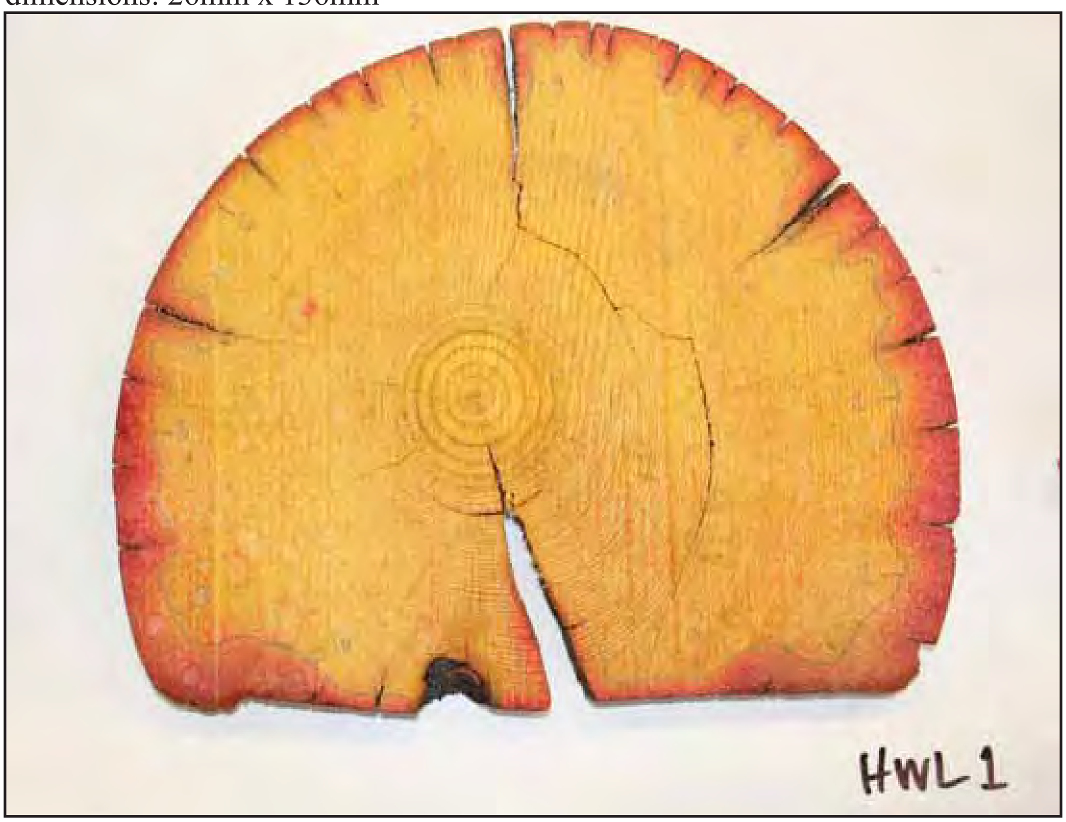


NWL1.1, Week 3 Testing, Sample Set 1, 20%MC and DOT in Water.
Approximate radial dimensions: 114mm & 98mm

Appendix B: Select Sample Photos

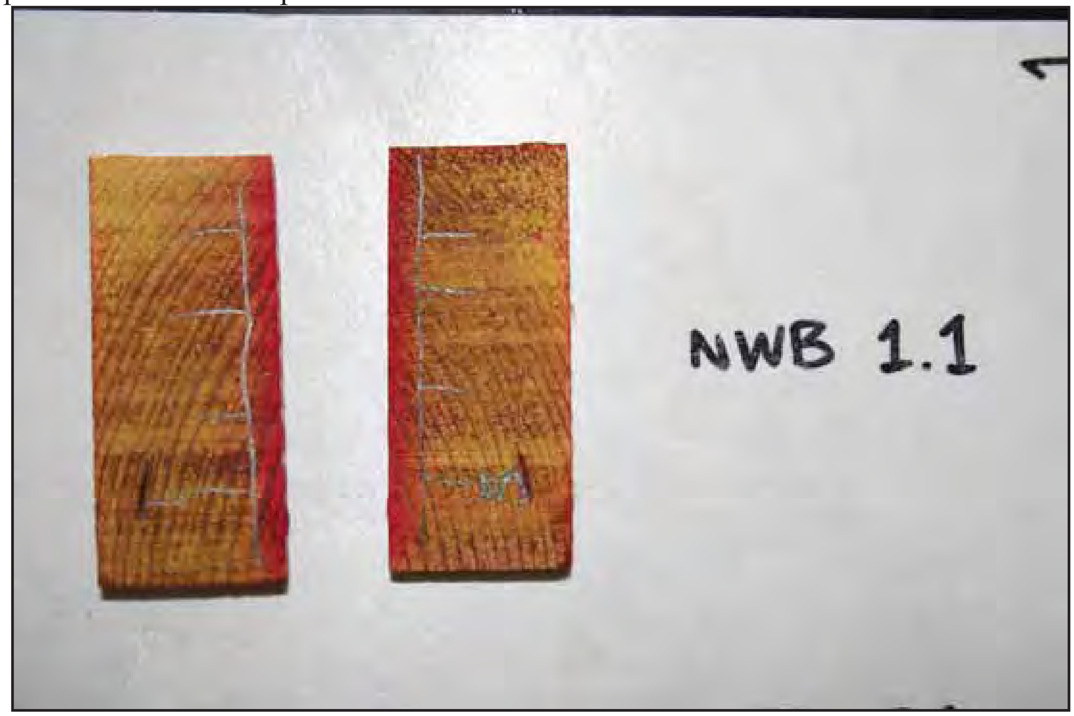


HWB1, Week 3 Testing, Sample Set 1, 20%MC and DOT in Water. Approximate dimensions: 26mm x 136mm

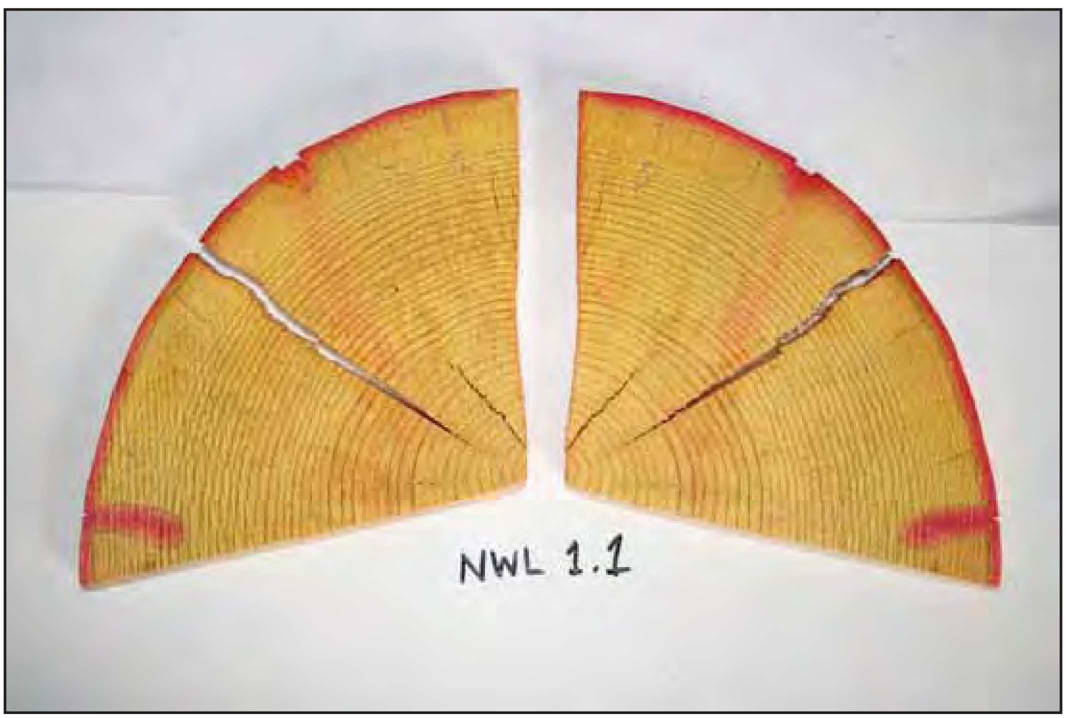


HWL1, Week 3 Testing, Sample Set 1, 20%MC and DOT in Water. Approximate width: 170mm

Appendix B: Select Sample Photos

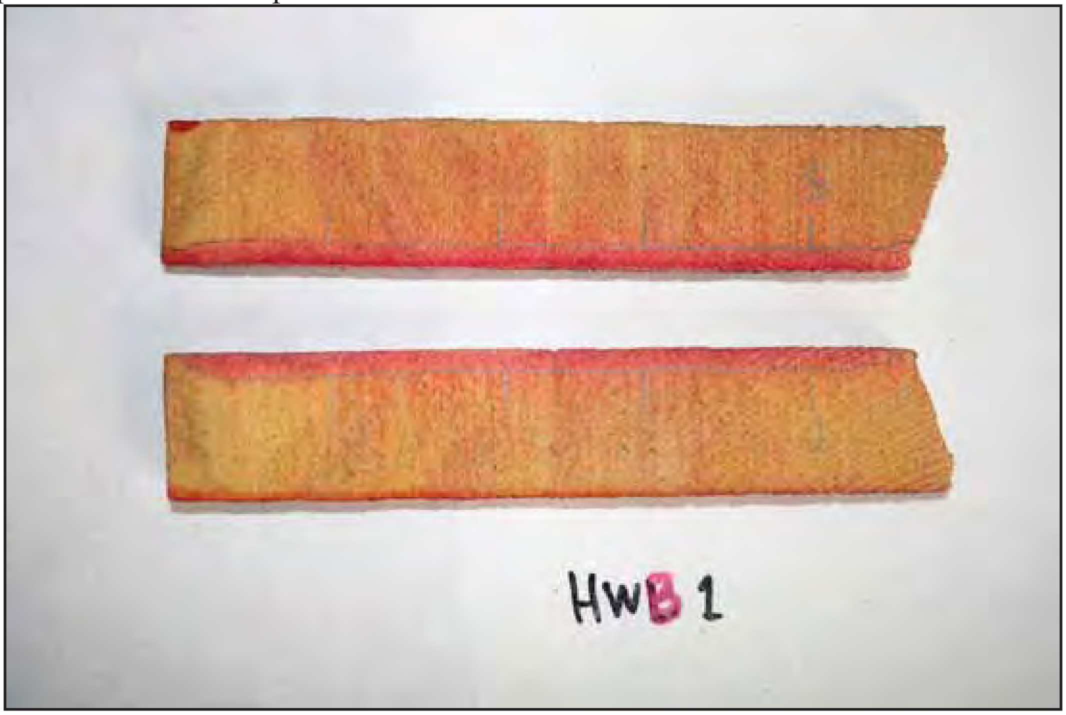


HWB1, Week 6 Testing, Sample Set 1, 20%MC and DOT in Water. Approximate dimensions: 26mm x 56mm

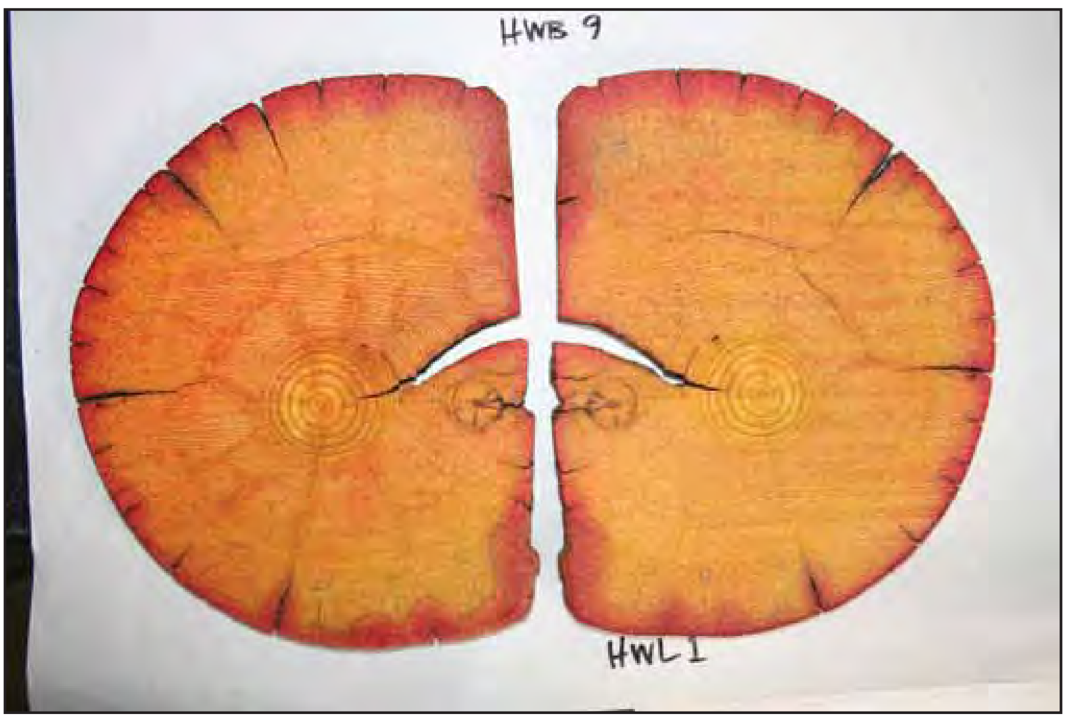


HWL1, Week 6 Testing, Sample Set 1, 20%MC and DOT in Water. Approximate radial dimensions: 114mm & 98mm

Appendix B: Select Sample Photos



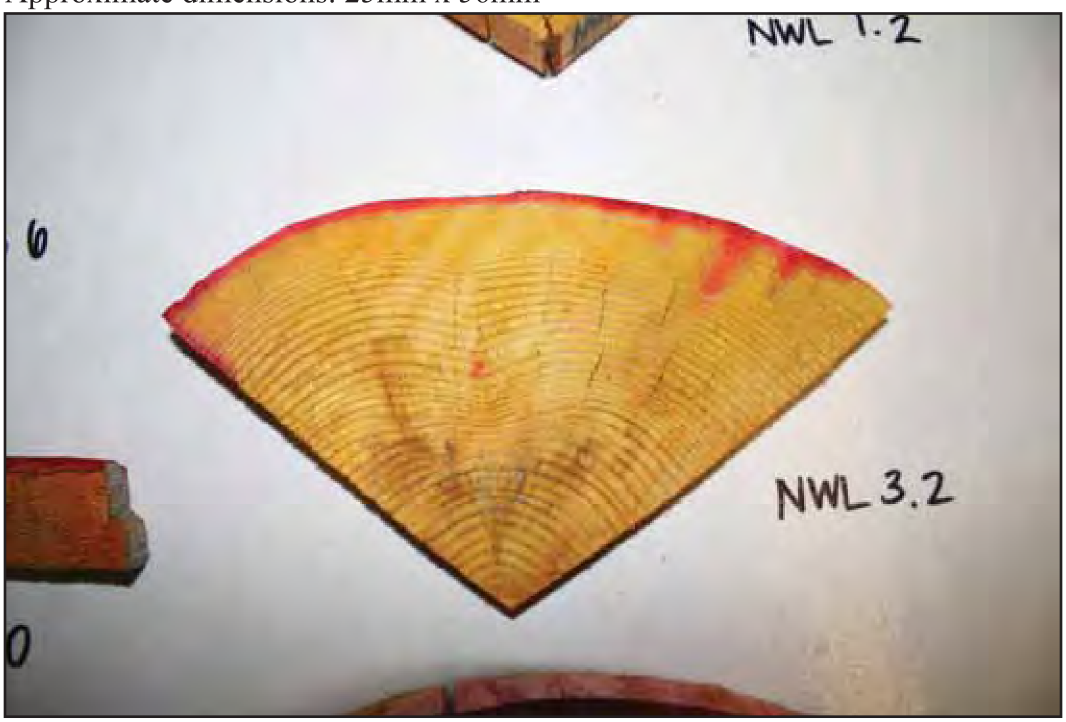
HWB1, Week 6 Testing, Sample Set 1, 20%MC and DOT in Water. Approximate dimensions: 26mm x 136mm



HWL1, Week 6 Testing, Sample Set 1, 20%MC and DOT in Water. Approximate width: 170mm

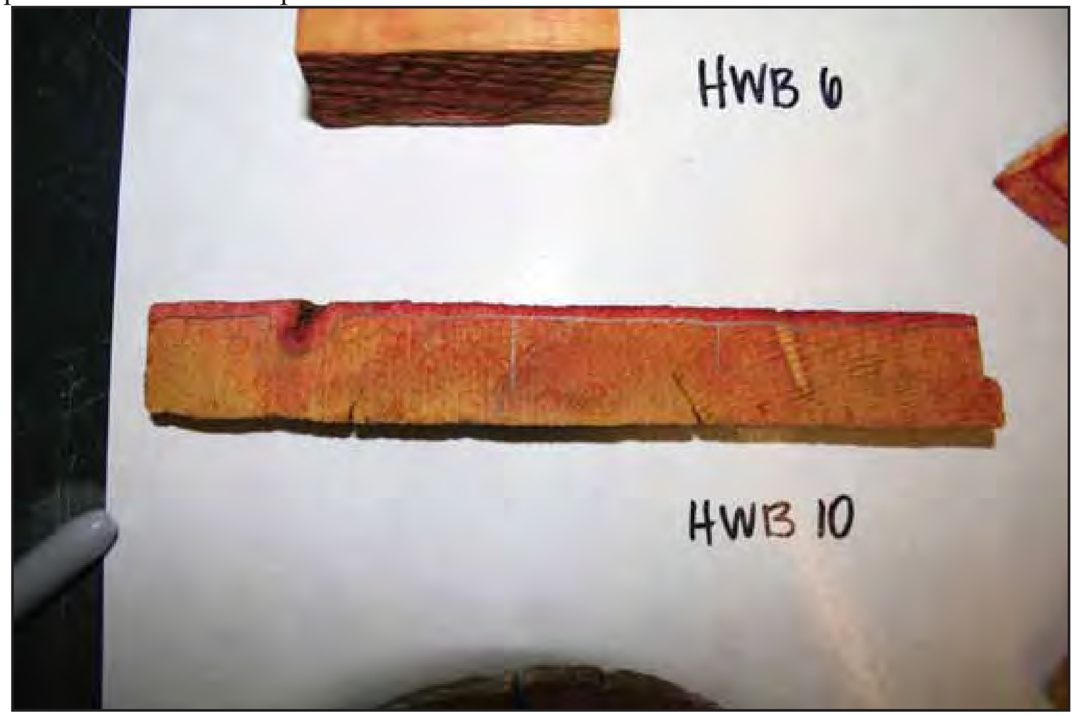
Appendix B: Select Sample Photos

NWB1.2, Week 1 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate dimensions: 25mm x 56mm

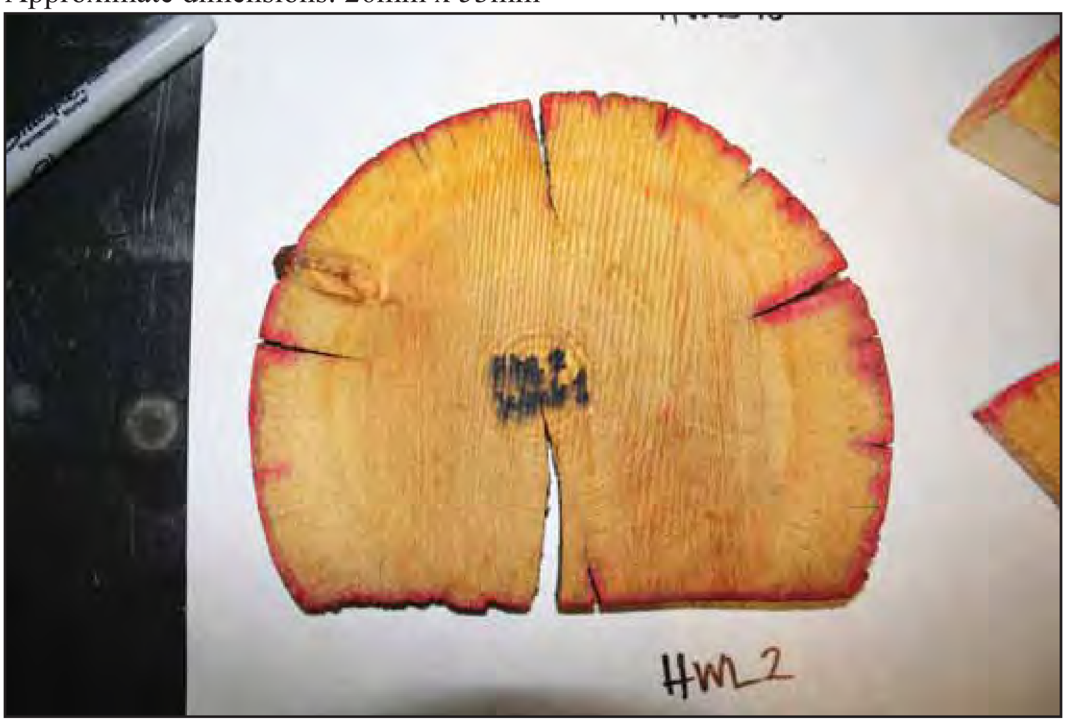


NWL3.2, Week 1 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate radial dimensions: 104mm & 111mm

Appendix B: Select Sample Photos

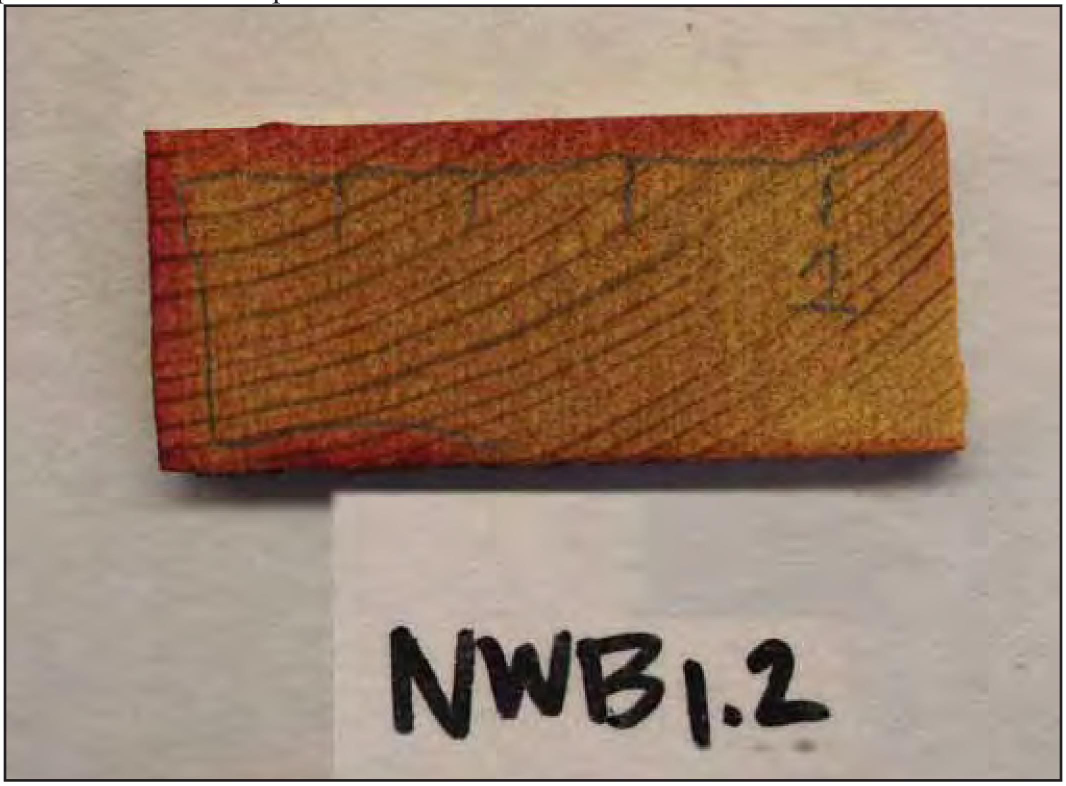


HWB10, Week 1 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate dimensions: 26mm x 53mm

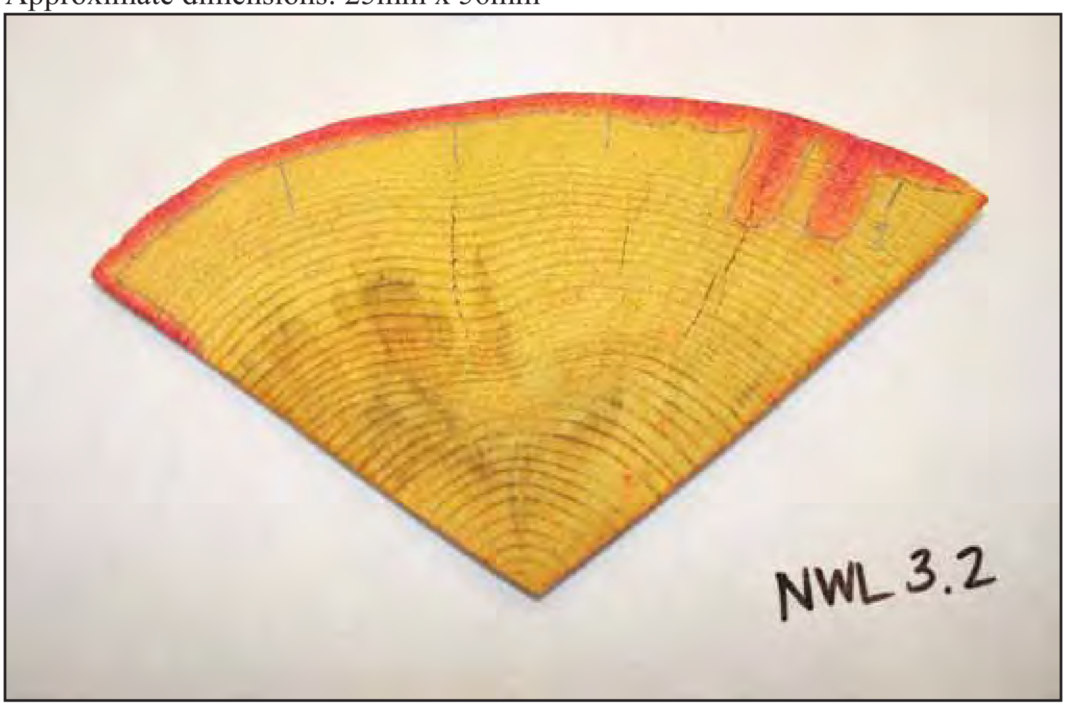


HWL2, Week 1 Testing, Sample Set 2, 40%MC and DOT in Water. Approximate width: 170mm

Appendix B: Select Sample Photos

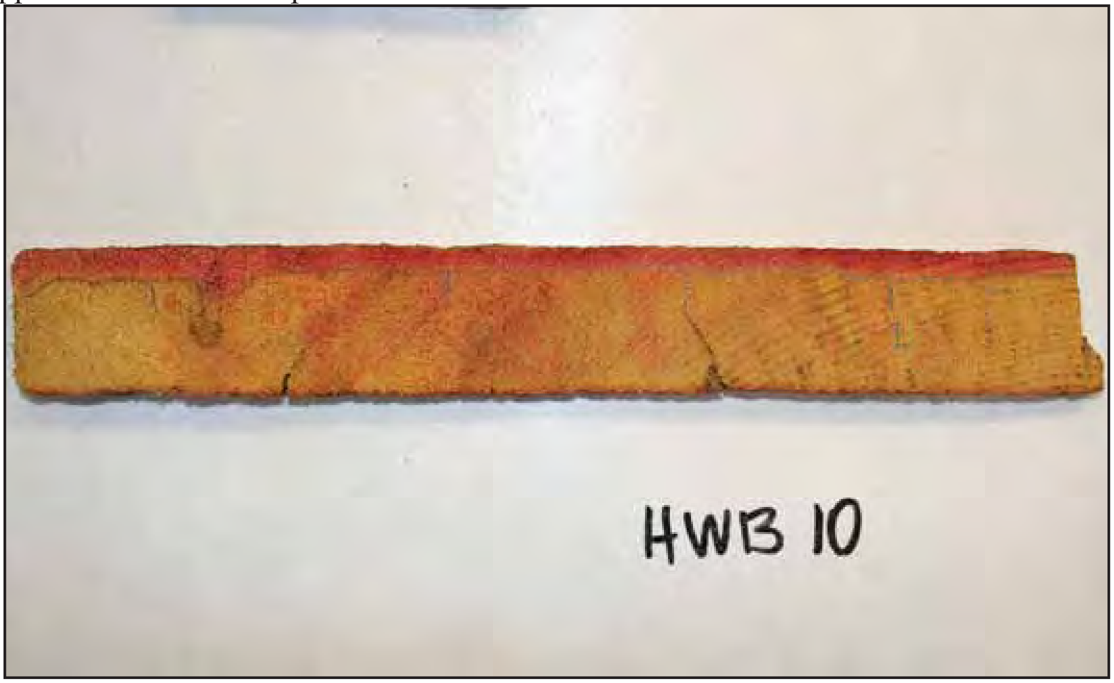


NWB1.2, Week 3 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate dimensions: 25mm x 56mm



NWL3.2, Week 3 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate radial dimensions: 104mm & 111mm

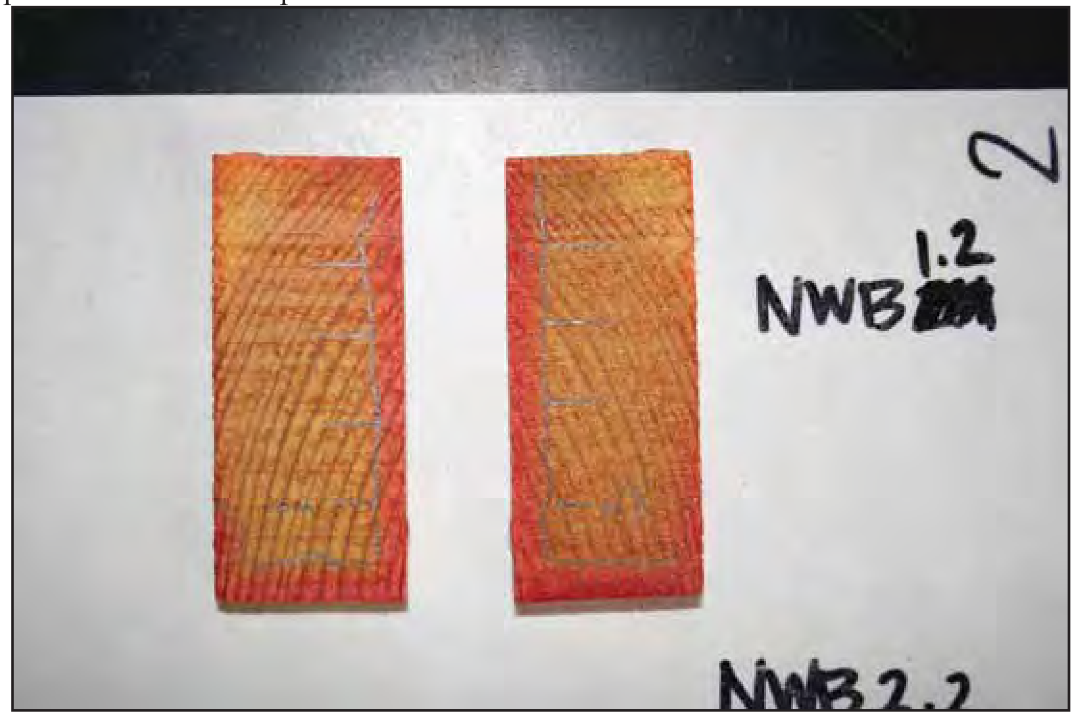
Appendix B: Select Sample Photos



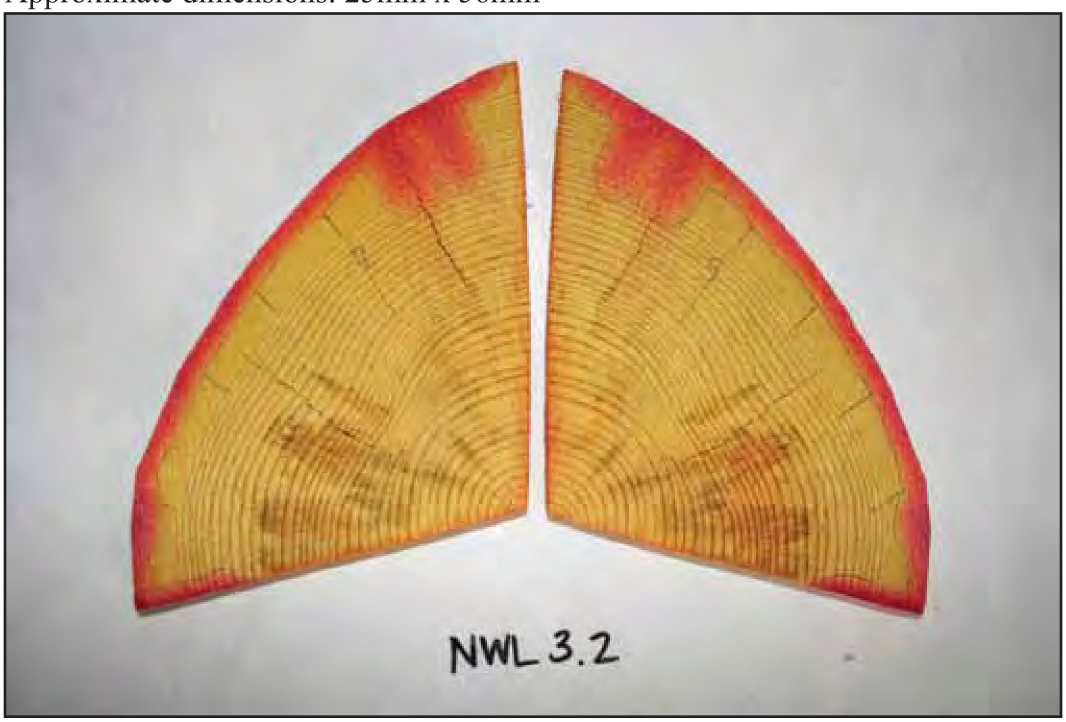
HWB10, Week 3 Testing, Sample Set 2, 40%MC and DOT in Water. Approximate dimensions: 26mm x 53mm

HWL2, Week 3 Testing, Sample Set 2, 40%MC and DOT in Water. Approximate width: 170mm

Appendix B: Select Sample Photos

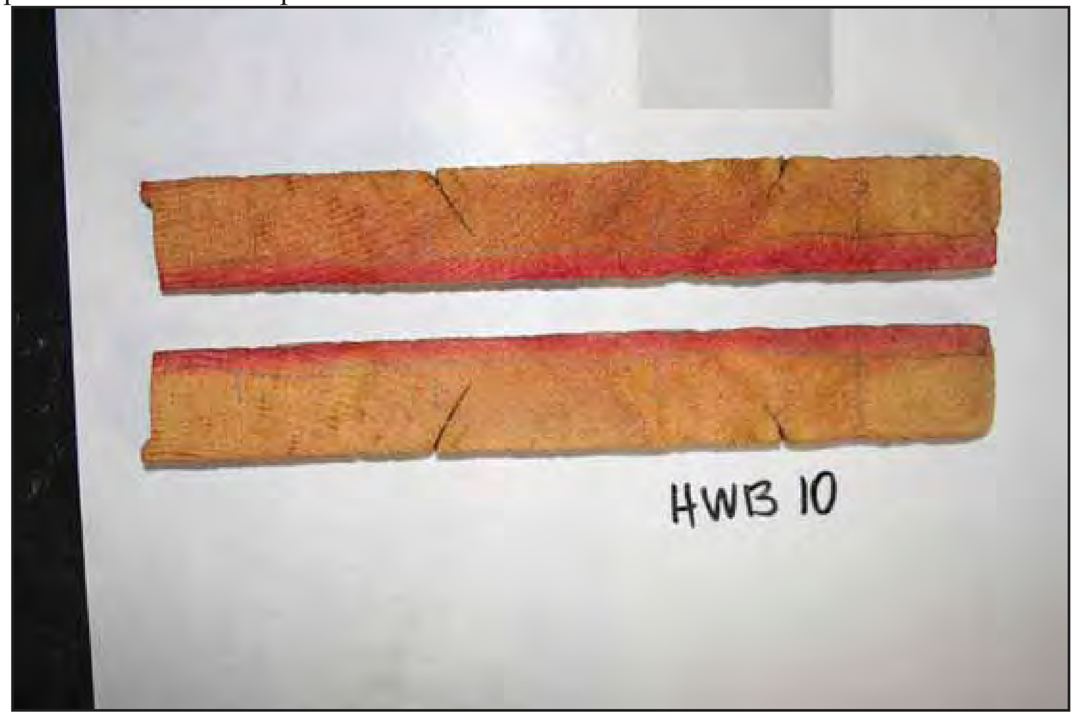


NWB1.2, Week 6 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate dimensions: 25mm x 56mm

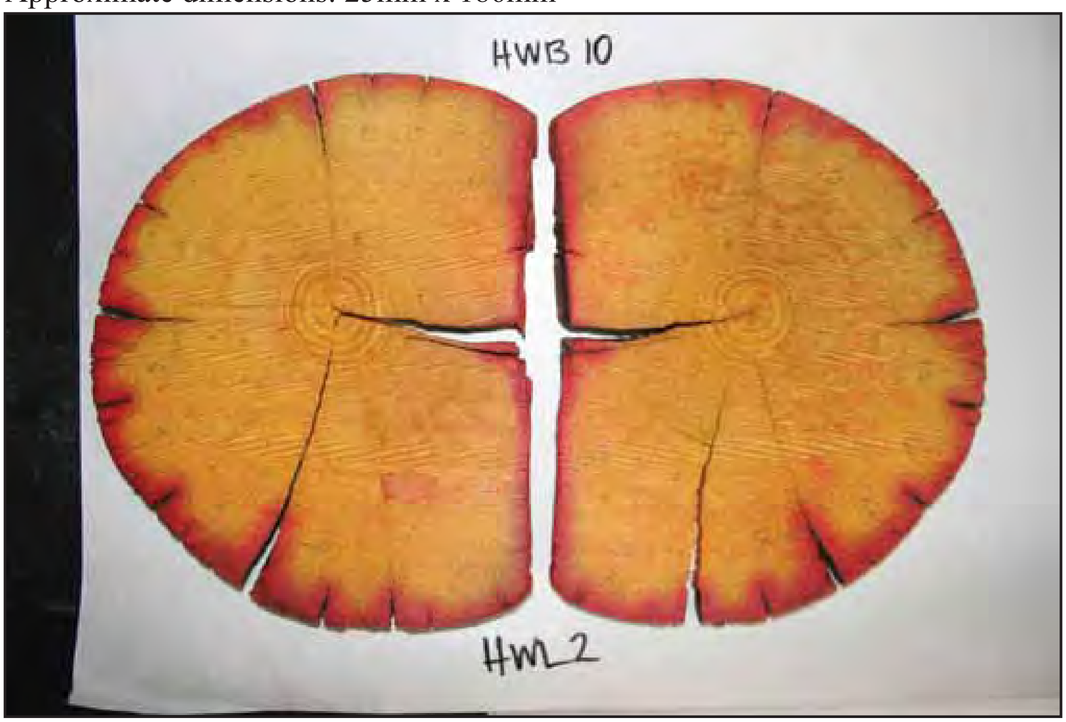


NWL3.2, Week 6 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate radial dimensions: 104mm & 111mm

Appendix B: Select Sample Photos

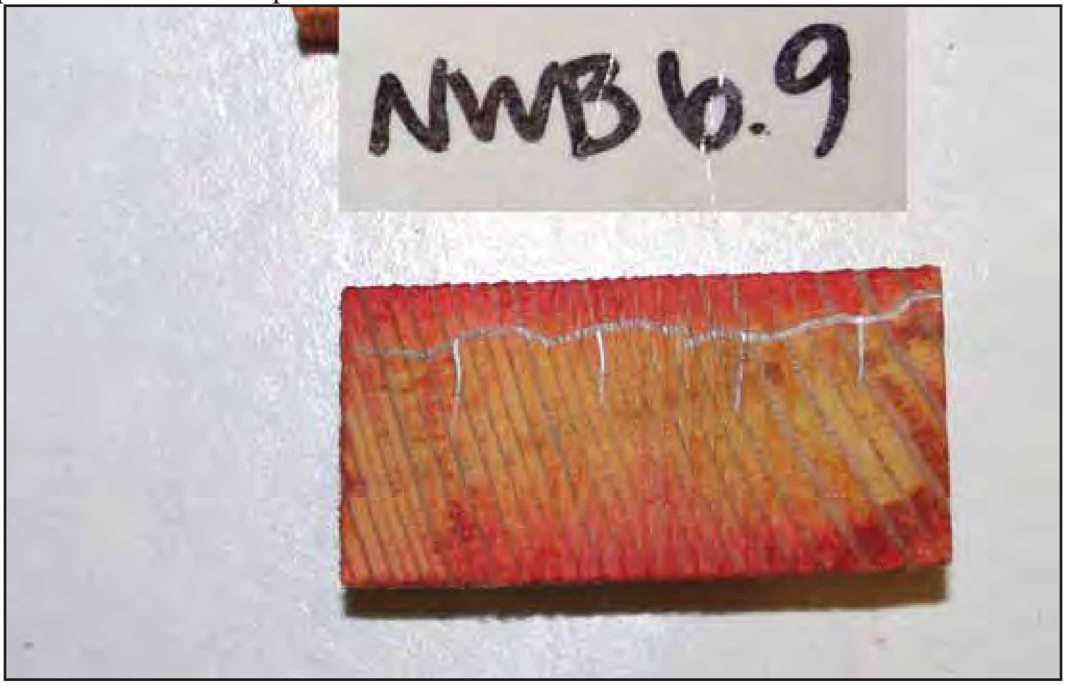


HWB10, Week 6 Testing, Sample Set 2, 40%MC and DOT in Water.
Approximate dimensions: 25mm x 186mm

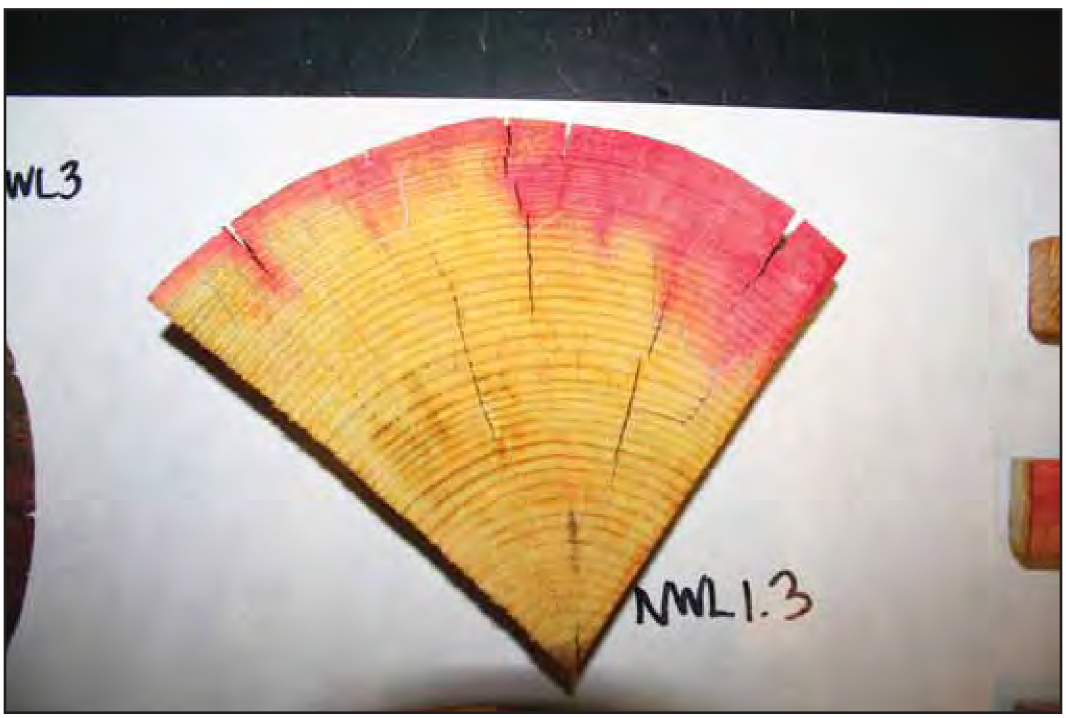


HWL2, Week 6 Testing, Sample Set 2, 40%MC and DOT in Water. Approximate width: 170mm

Appendix B: Select Sample Photos



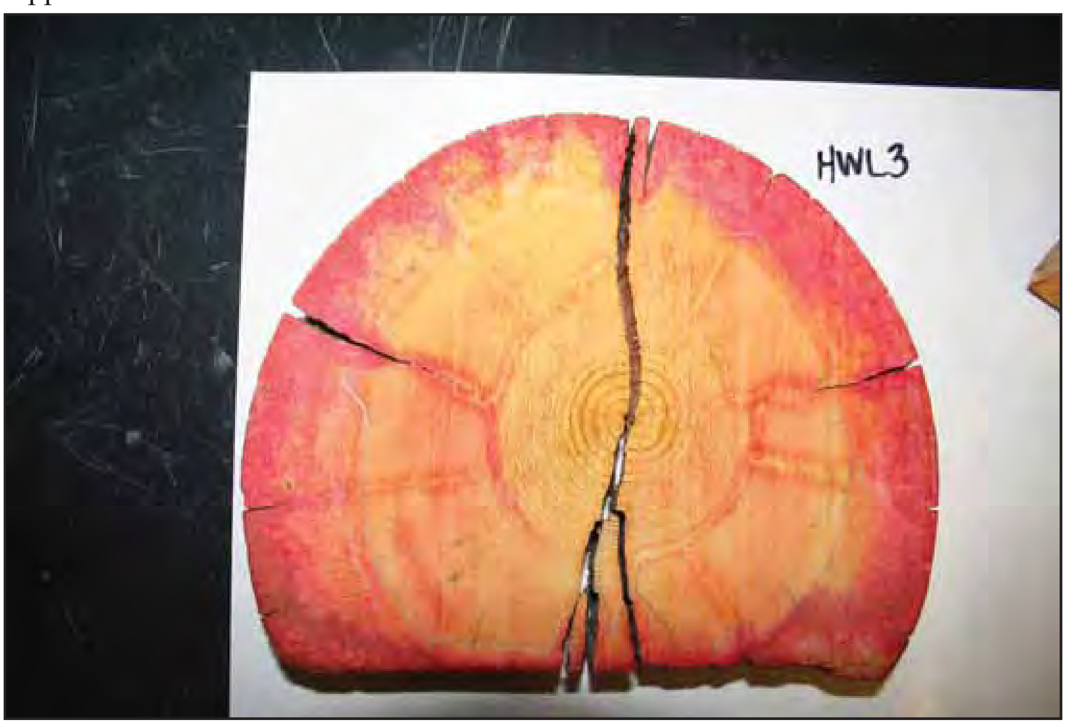
NWB6.9, Week 1 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate dimensions: 25mm x 51mm



NWL1.3, Week 1 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate radial dimensions: 113mm & 125mm

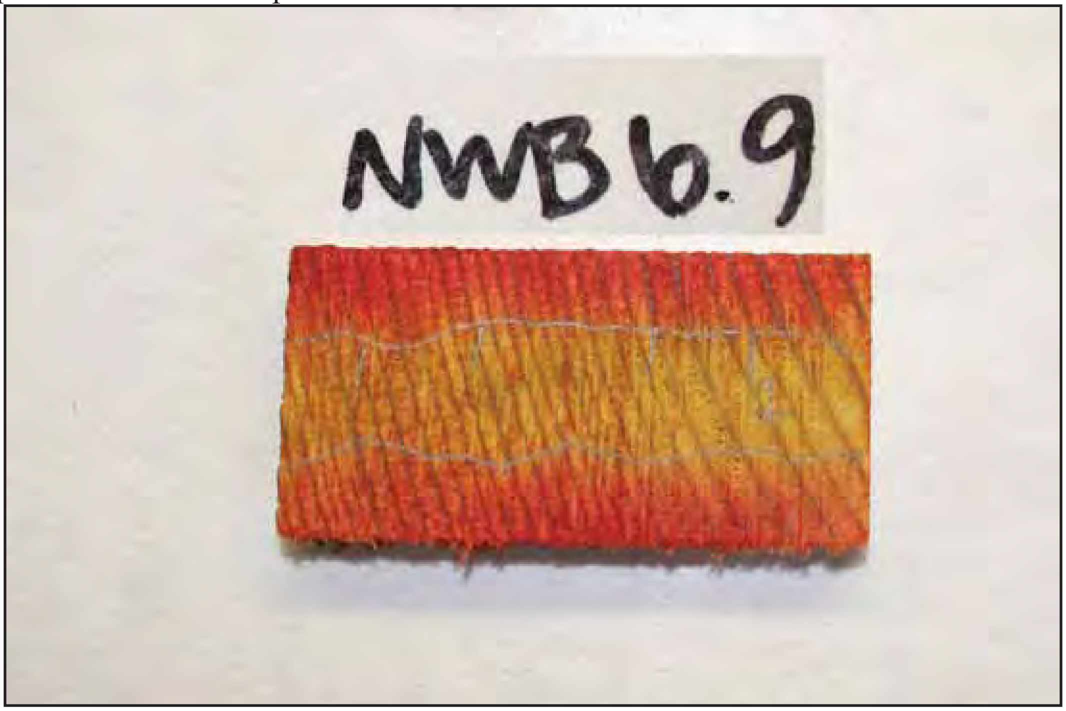
Appendix B: Select Sample Photos

HWB7, Week 1 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate dimensions: 25mm x 66mm

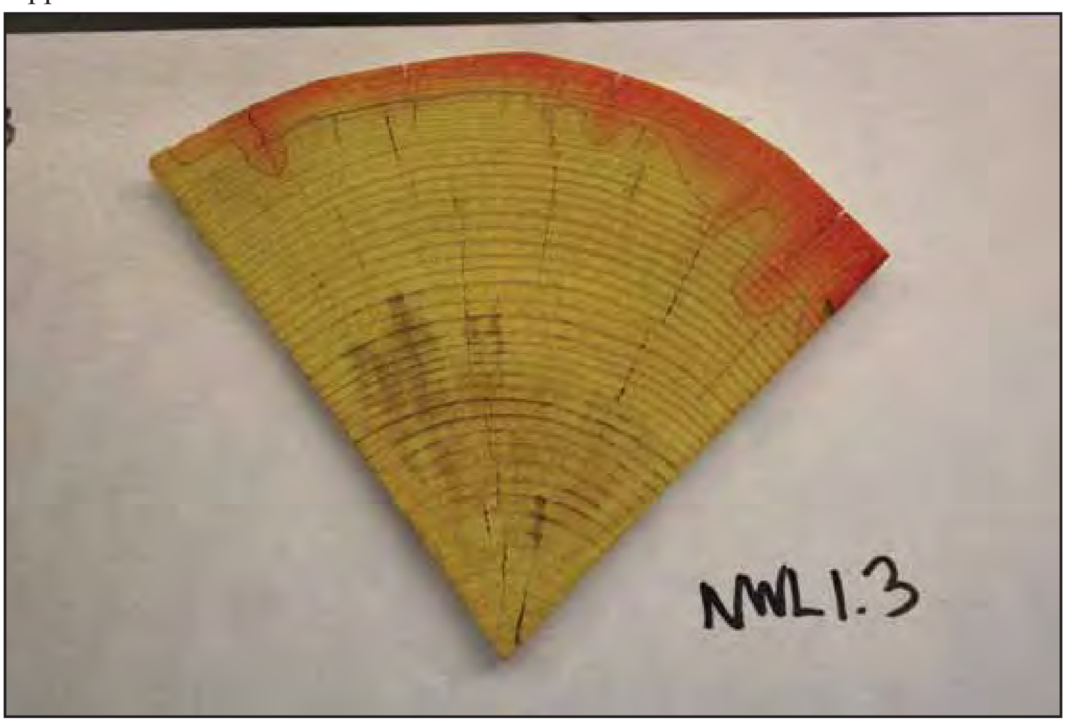


HWL3, Week 1 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate width: 170mm

Appendix B: Select Sample Photos

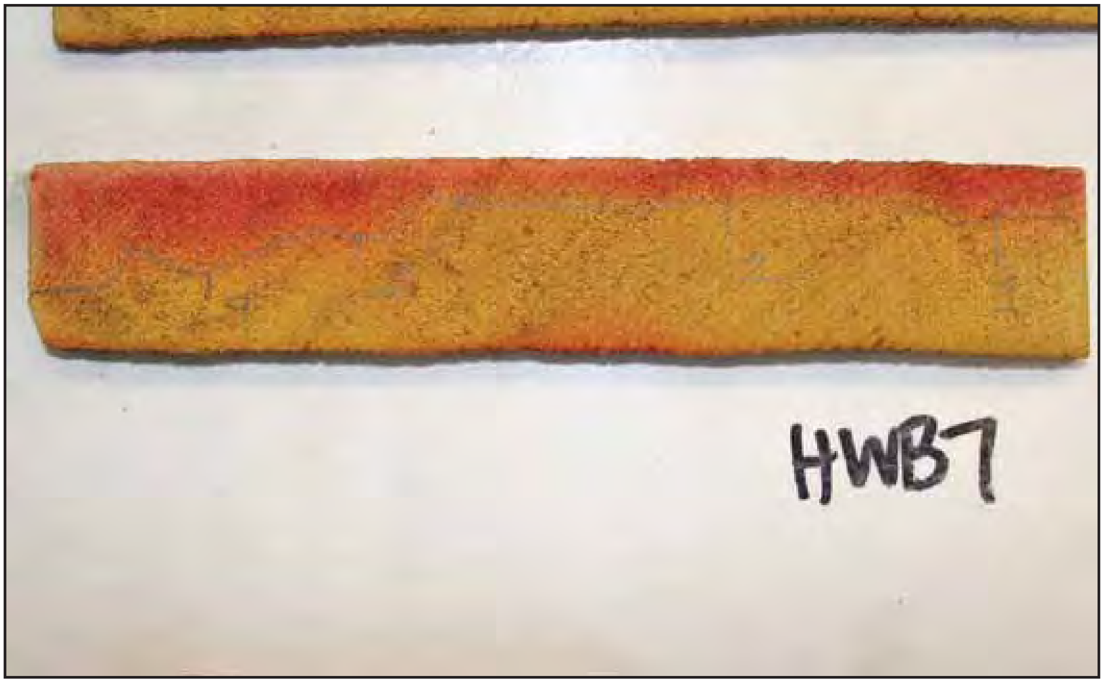


NWB6.9, Week 3 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate dimensions: 26mm x 51mm

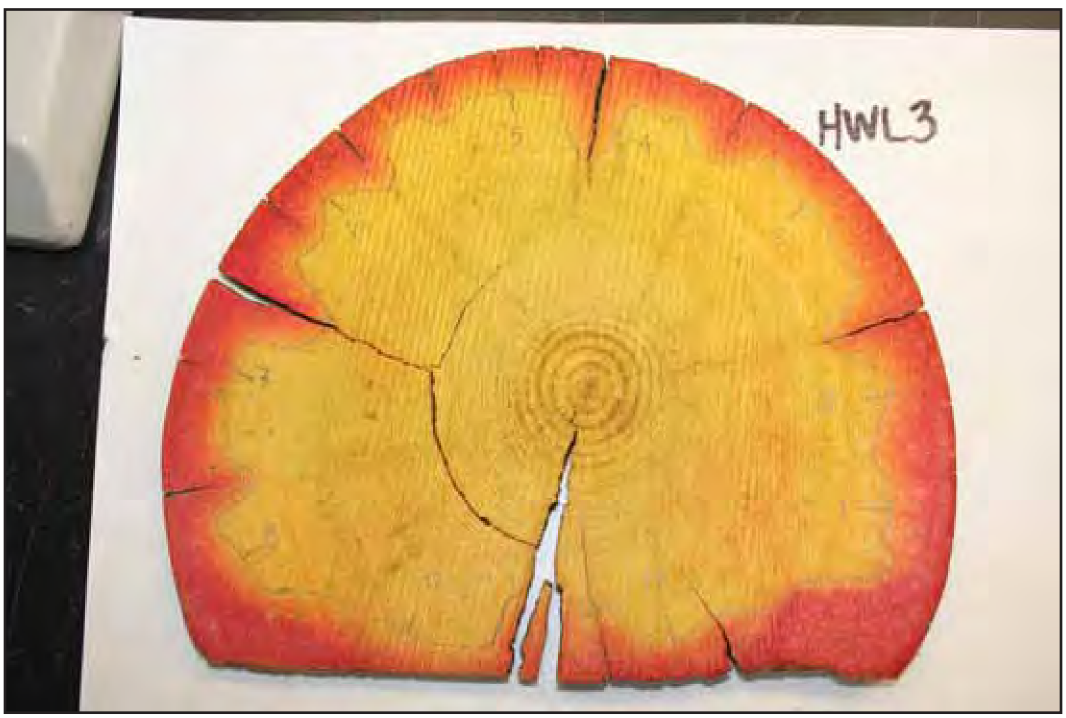


NWL1.3, Week 3 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate radial dimensions: 114mm & 128mm.

Appendix B: Select Sample Photos



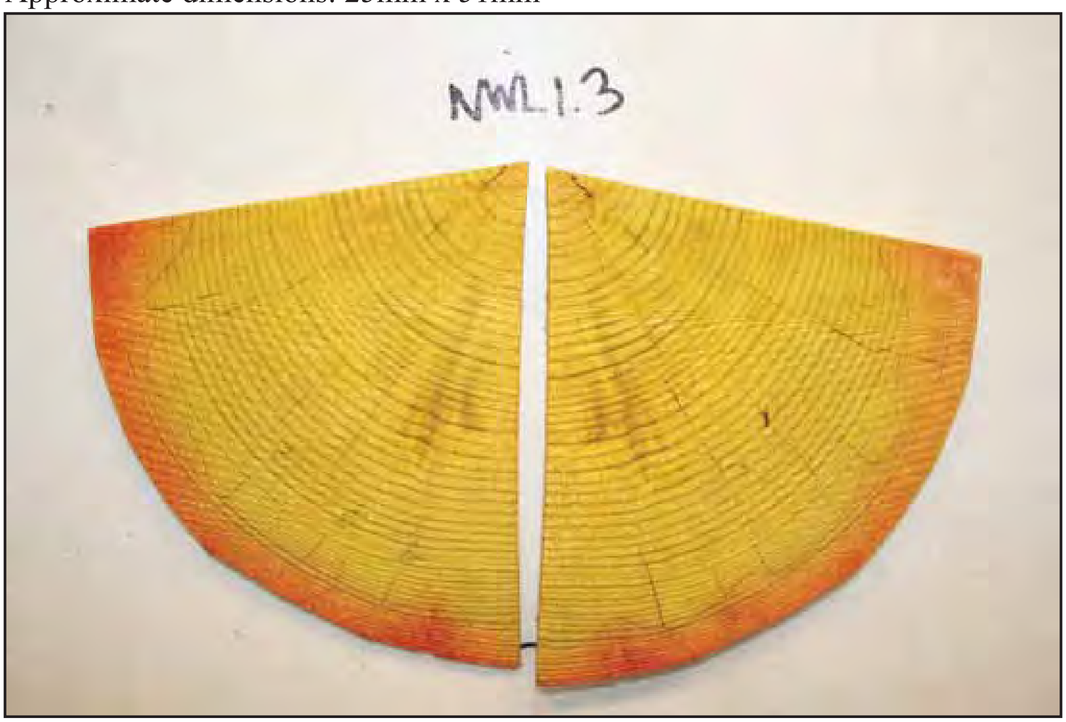
HWB7, Week 3 Testing, Sample Set 3, 20%MC and DOT in Glycols. Approximate dimensions: 26mm x142mm



HWL3, Week 3 Testing, Sample Set 3, 20%MC and DOT in Glycols. Approximate width: 170mm

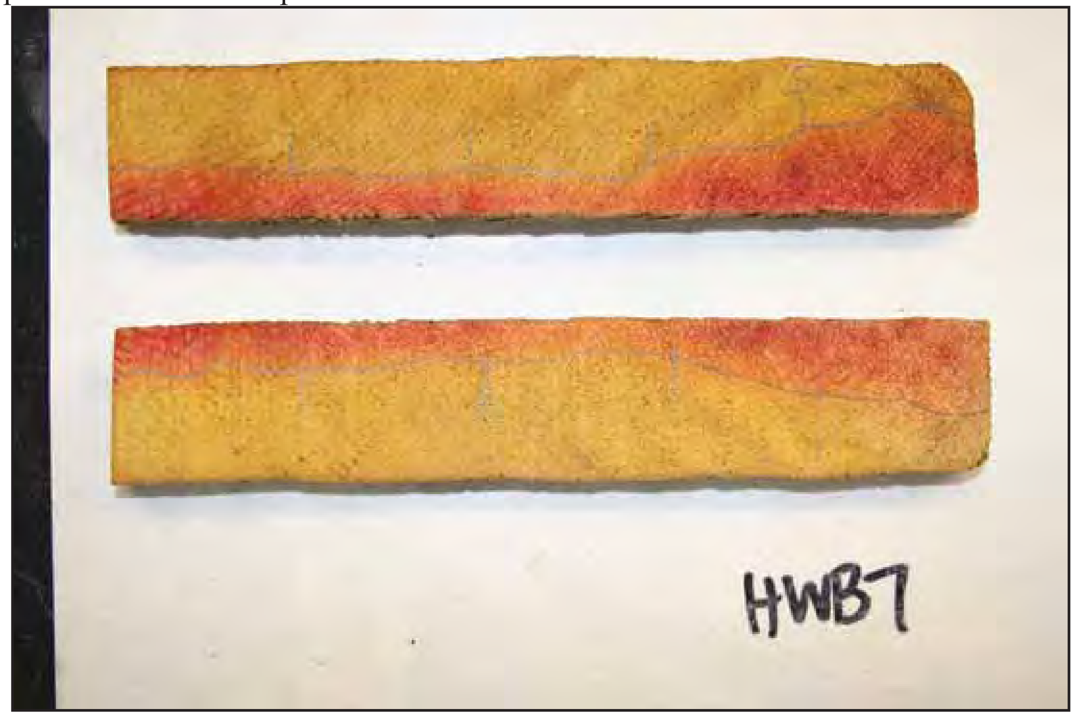
Appendix B: Select Sample Photos

NWB6.9, Week 6 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate dimensions: 25mm x 51mm

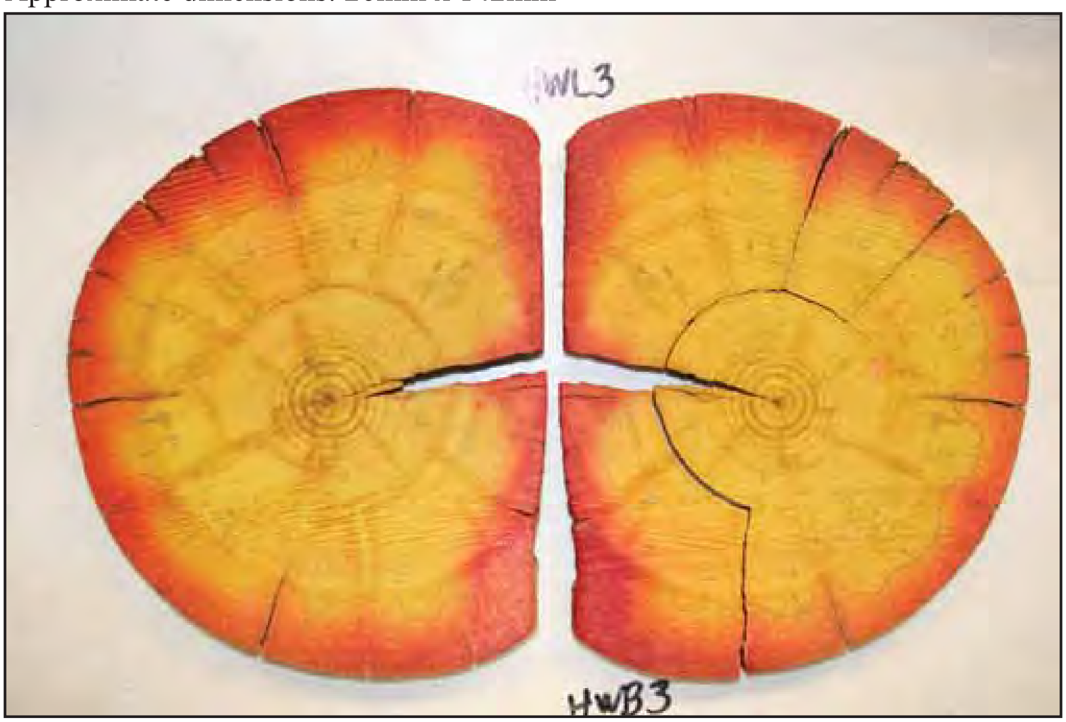


NWL1.3, Week 6 Testing, Sample Set 3, 20%MC and DOT in Glycols:
Approximate radial dimensions: 128mm x 112mm

Appendix B: Select Sample Photos

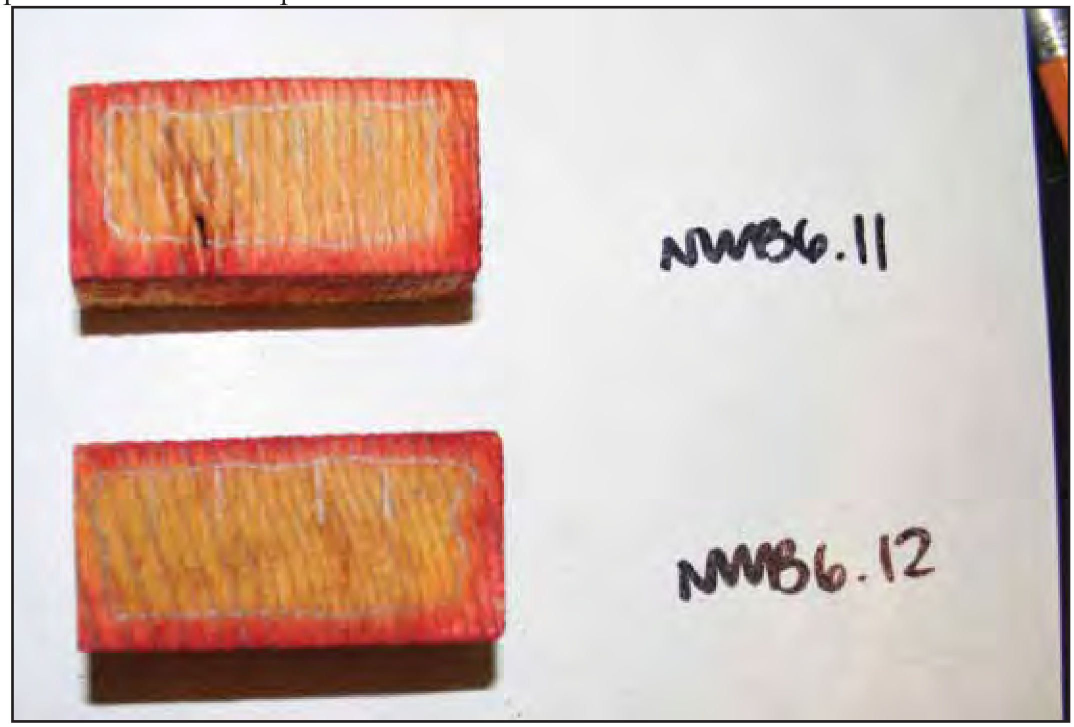


HWB7, Week 6 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate dimensions: 26mm x 142mm

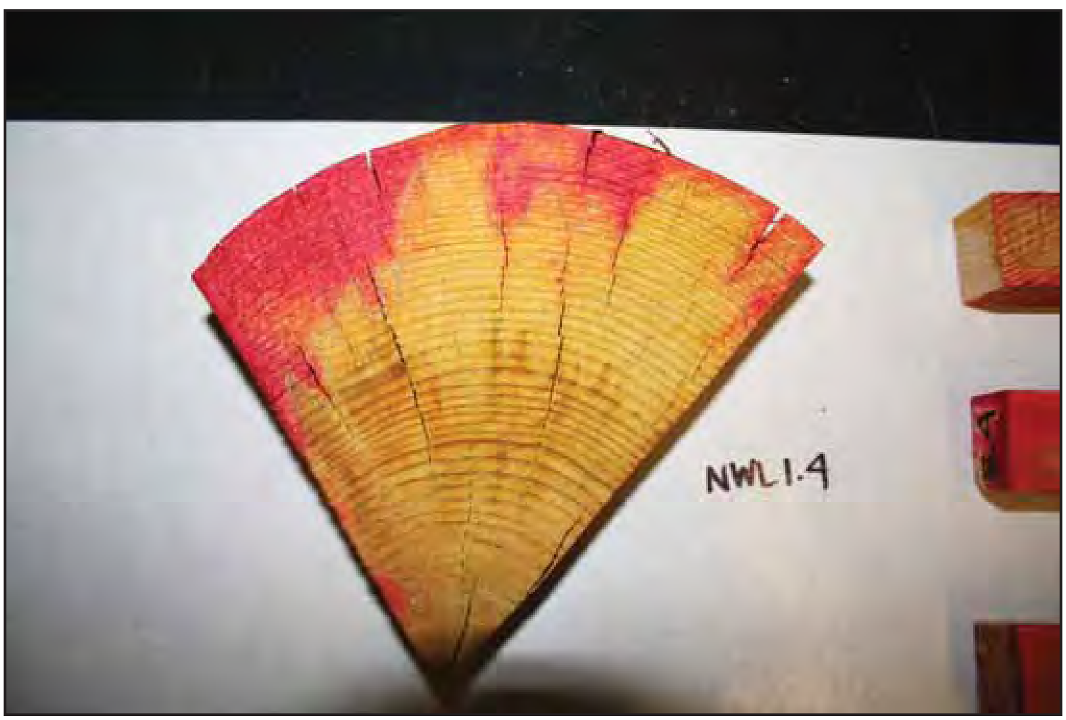


HWL3, Week 6 Testing, Sample Set 3, 20%MC and DOT in Glycols.
Approximate width: 170mm

Appendix B: Select Sample Photos

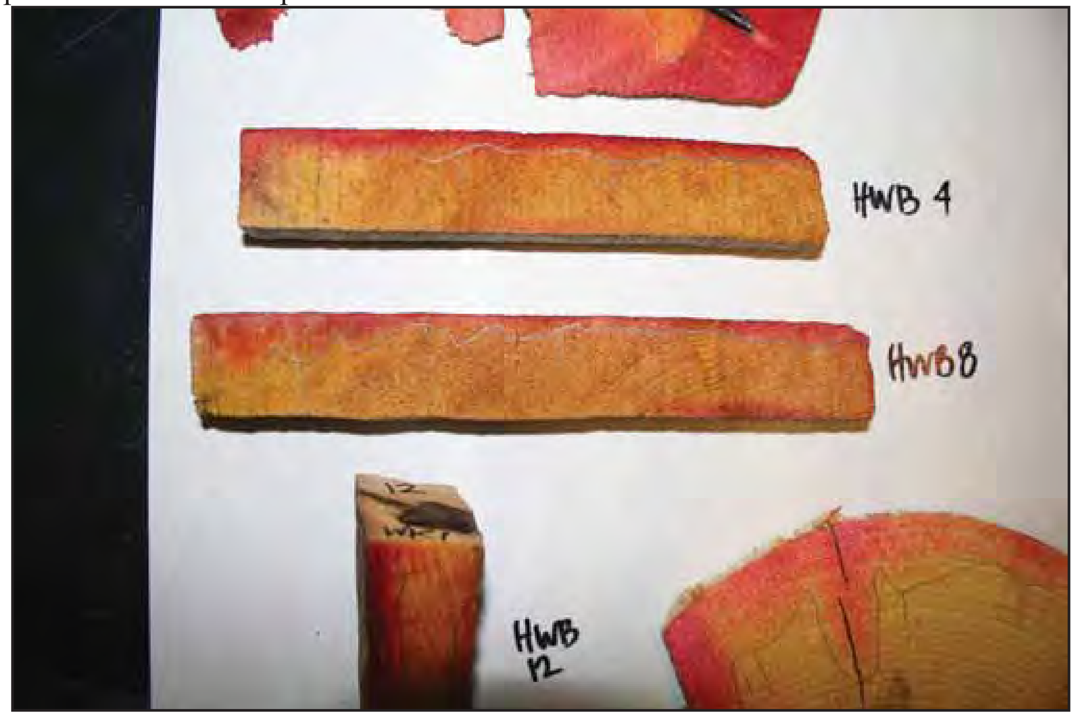


NWB6.11 & NWB6.12, Week 1 Testing, Sample Set 4, 40%MC and DOT in Glycols. Approximate dimensions: 25mm x 51mm



NWL1.4, Week 1 Testing, Sample Set 4, 40%MC and DOT in Glycols. Approximate dimensions: 130mm x 103mm.

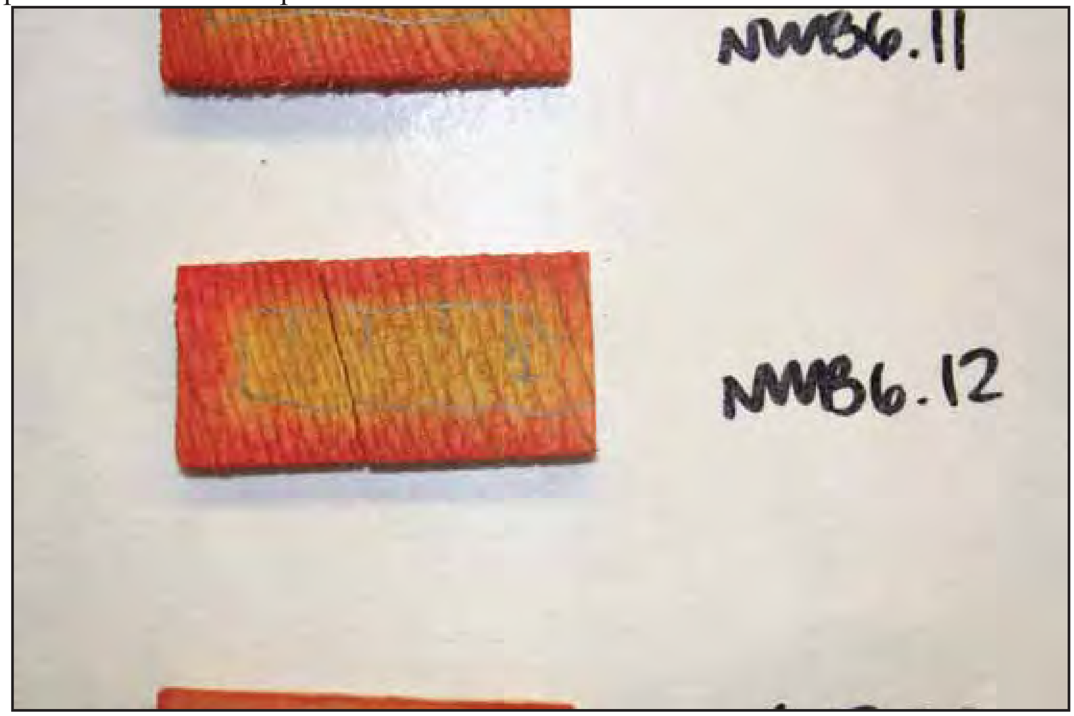
Appendix B: Select Sample Photos



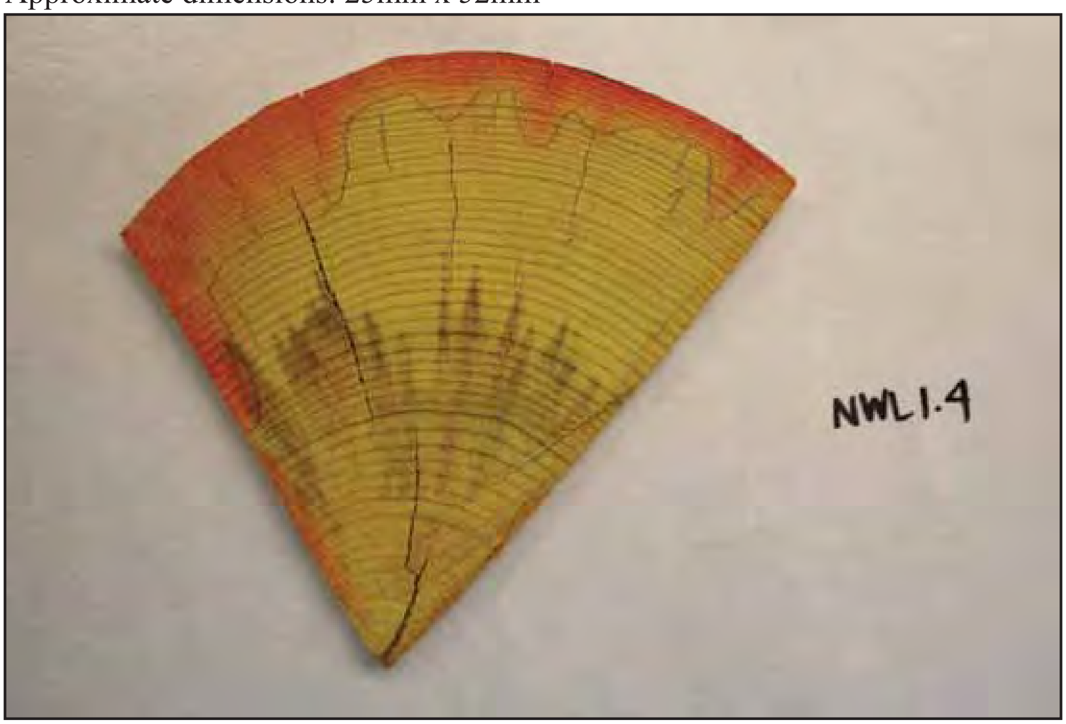
HWB4 & HWB8, Week 1 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate dimensions: 26mm x 148mm &173mm

HWL4, Week 1 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate width: 170mm.

Appendix B: Select Sample Photos

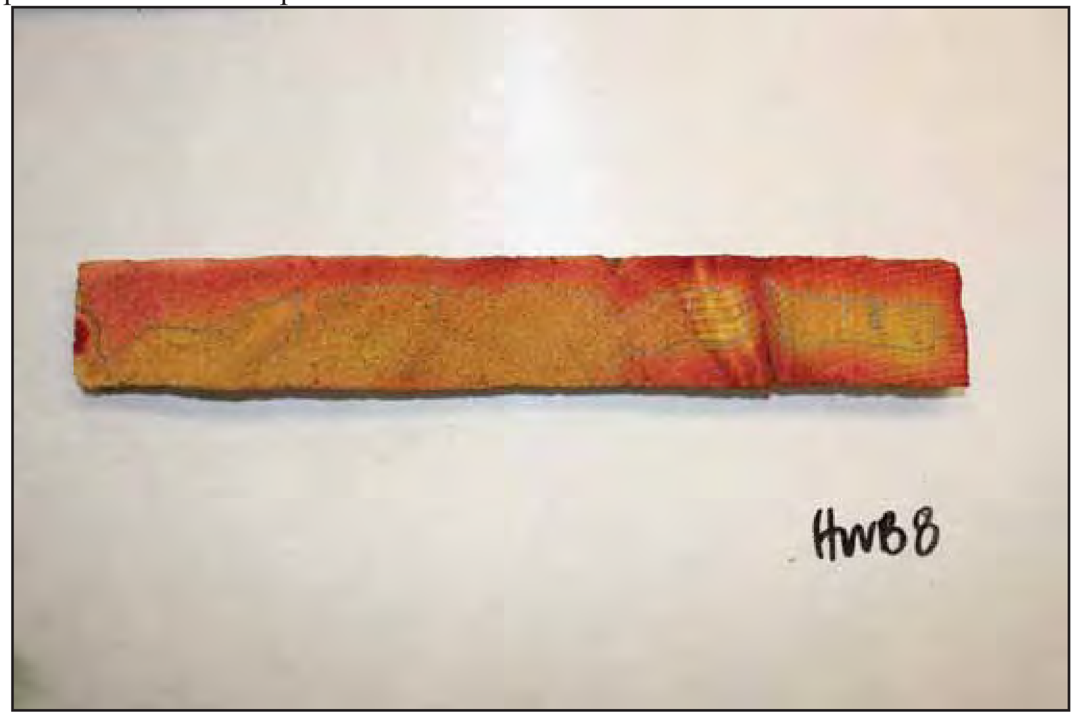


NWB6.12, Week 3 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate dimensions: 25mm x 52mm

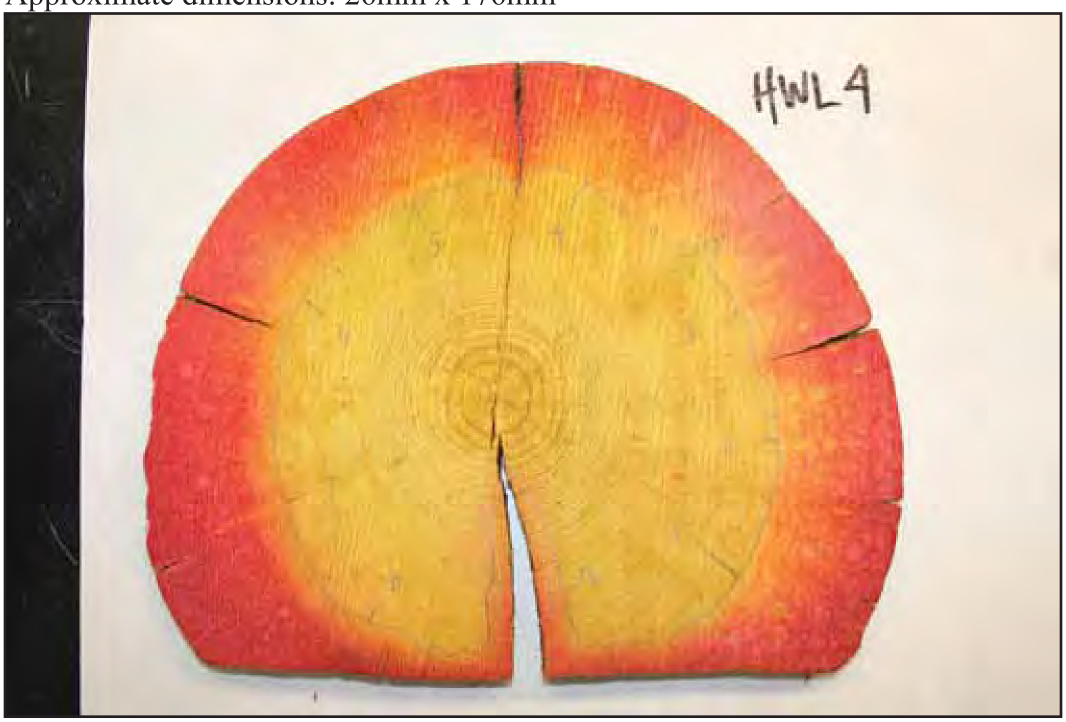


NWL1.4, Week 3 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate radial dimensions: 104mm & 130mm

Appendix B: Select Sample Photos

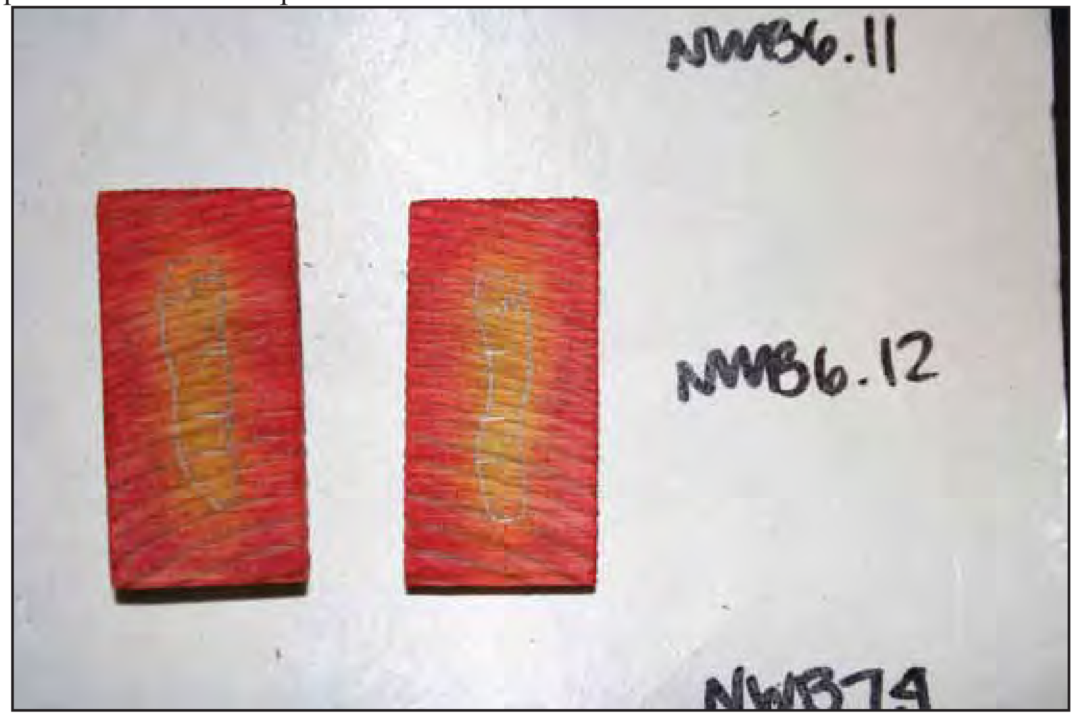


HWB8, Week 3 Testing, Sample Set 4, 40%MC and DOT in Glycols:
Approximate dimensions: 26mm x 176mm

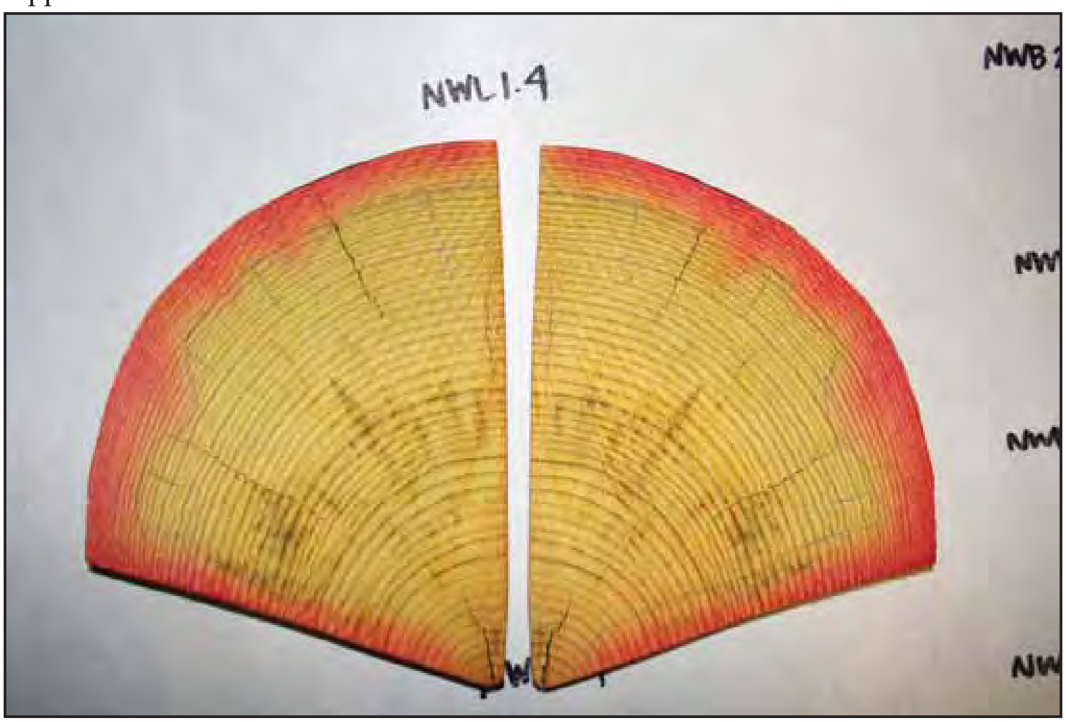


HWL4, Week 3 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate width: 170mm

Appendix B: Select Sample Photos

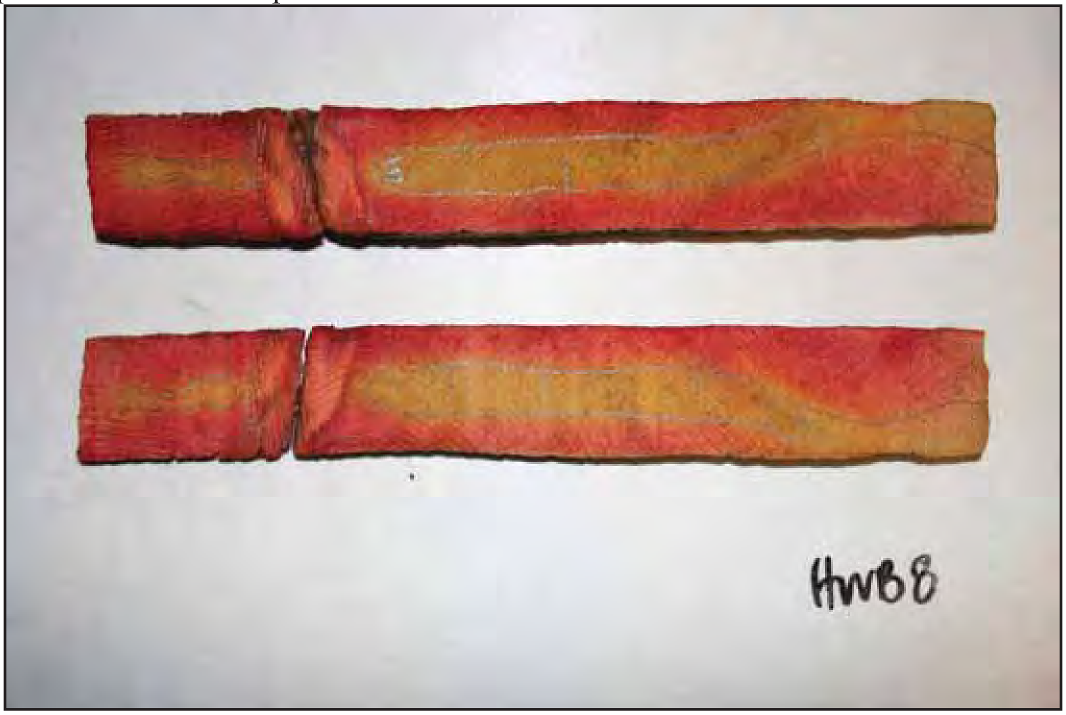


NWB6.12, Week 6 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate dimensions: 26mm x 51mm

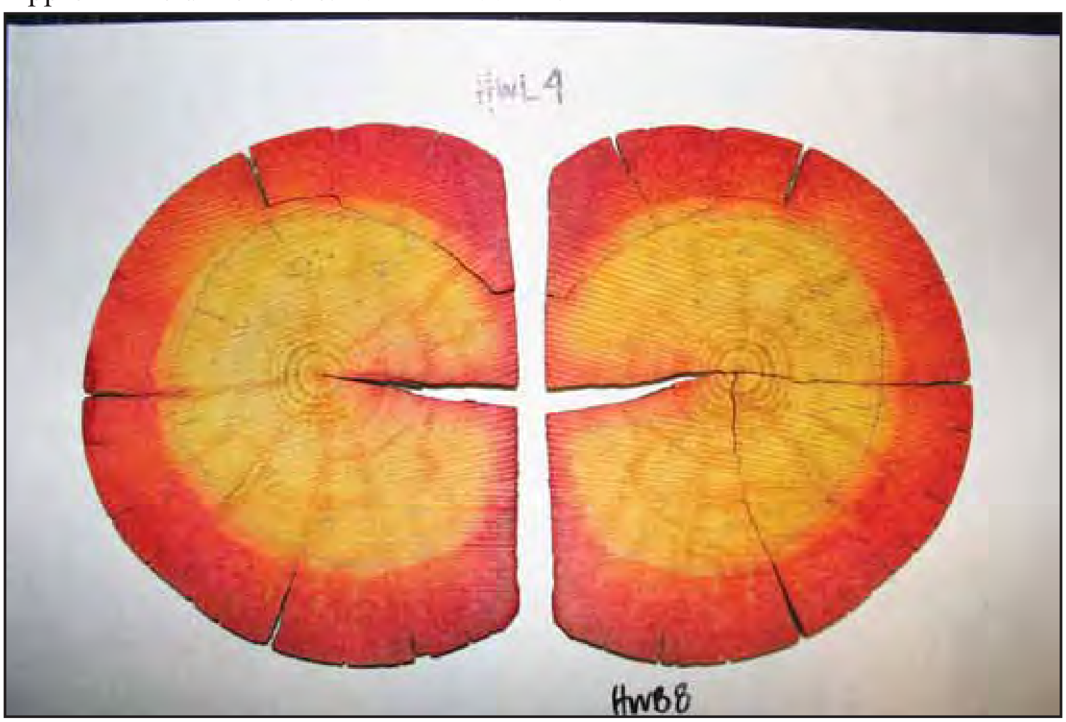


NWL1.4, Week 6 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate radial dimensions: 107mm & 131mm

Appendix B: Select Sample Photos



HWB8, Week 6 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate dimensions: 26mm x 180mm.



HWL4, Week 6 Testing, Sample Set 4, 40%MC and DOT in Glycols.
Approximate width: 170mm

Appendix C: Supplier List

FISHER SCIENTIFIC
Liberty Lane
Hampton, NH 03842
800.766.7000
http://www.fishersci.com
All reagent chemicals and other laboratory supplies unless otherwise noted.

NISUS CORP
100 Nisus Drive
Rockford, TN 37853
800.264.0870
http://www.nisuscorp.com
BoraCare and Tim-Bor

Appendix D: Kraemer and McGovern Building Photographs

Figure A1: The Kraemer and McGovern Buildings as seen from above. The buildings are in the center of the photograph.

Figure A2: West facade of the Kraemer Building.

Appendix D: Kraemer and McGovern Building Photographs

Figure A3: Front (south) facade of Kraemer and McGovern Buildings.

Figure A4: East facade of McGovern Building.

Appendix D: Kraemer and McGovern Building Photographs

Figure A5: Rear facade of Kraemer and McGovern Buildings.

Figure A5: Rear facade of Kraemer and McGovern Buildings.

Appendix D: Kraemer and McGovern Building Photographs

Figure A6: Room A in the McGovern Building, showing the many goods on display.

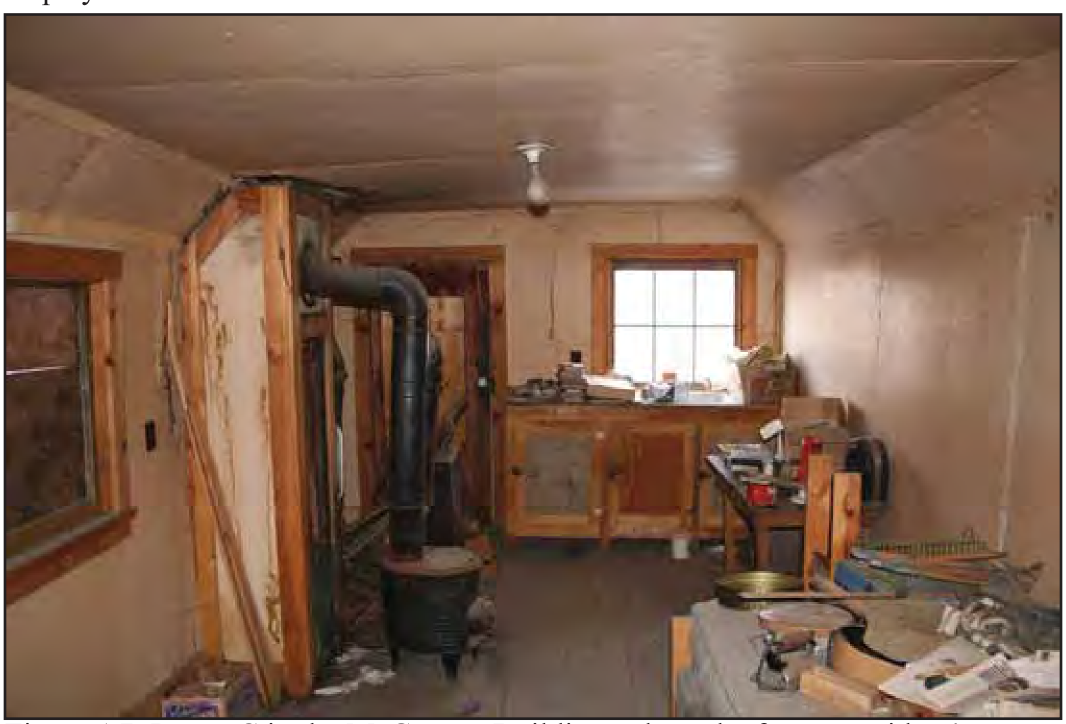


Figure A7: Room C in the McGovern Building, where the former resident's belongings are still scattered about, untouched since his death, nearly 50 years ago.

Figure A8: Room D in the McGovern Building, with a Bovey mannequin visible on the left side.

Figure A9: Room E in the McGovern Building. On the right side of the photo, the wall where the collapse took place is visible.

Figure A10: Room M in the McGovern Building, set up like a barber shop and dentist office.

Appendix D: Kraemer and McGovern Building Photographs

Figure A11: Dental tools on display in Room M of the McGovern Building.

Figure A12: Dental slides, manufactured in Philadelphia, on display in the dentist office in Room M of the McGovern Building.

Figure A13: Room R in the Kraemer Building.

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